TROPICAL NUTRITION AND DIETETICS

By

LUCIUS NICHOLLS

M.D., B.C., B.A. (Cantab.)

DIRECTOR OF BACTERIOLOGICAL AND PASTEUR INSTITUTES
AND DIRECTOR OF DIVISION OF NUTRITION, CEYLON,
LECTURER ON NUTRITION, CEYLON UNIVERSITY,
LATE LECTURER ON TROPICAL MEDICINE,
CEYLON MEDICAL COLLEGE

SECOND EDITION

REWRITTEN AND ENLARGED

LONDON
BAILLIÈRE, TINDALL AND COX
7 AND 8, HENRIETTA STREET, COVENT GARDEN, W.C.2

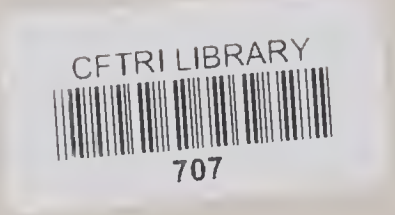
1945

707

"Where one step broken the great scale's destroyed
From nature's chain whatever link you strike,
Tenth or ten thousandth, breaks the chain alike.
And if each system in gradation roll
Alike essential to the amazing whole.
The least confusion, but in one, not all
That system only but the whole must fall."

ALEXANDER POPE

L;326.792 N45



PRINTED IN GREAT BRITAIN

PREFACE TO SECOND EDITION

When the first edition of this book was written in 1937 several important vitamins, including nicotinic acid and vitamin K, had not been discovered, consequently the book was in some respects out of date by the time it was published. This is the fate of all books dealing with subjects undergoing rapid development.

It appears fairly certain, however, that all the more important vitamins, sometimes called the *major vitamins*, are now known. They have been isolated or synthesized in pure form ; the effects of deficiencies of them from diets have been widely studied ; some of the parts they play in metabolic processes have been revealed ; and the amounts of them in various foodstuffs have been determined.

Several *minor vitamins* have been discovered in recent years, and doubtless others remain to be discovered. Most of them are of less importance than the major vitamins to the extent that they are very unlikely to be deficient from human diets. It is probable, however, that the absorption of some of them from the alimentary tract, or their metabolic actions within the body may be diminished in certain diseases, or that poisons or bacterial toxins may destroy them or inhibit the physiological processes of them, and these effects would have important therapeutic implications.

Much has also recently been discovered concerning a few minerals which, because they are present in exceedingly minute amounts in foodstuffs, have been called the " trace " elements. The dietary needs in animal nutrition of some of the trace elements have been proved.

The great enlargement of this edition is due to (1) the incorporation of much recent knowledge of the constituents of foodstuffs ; (2) the inclusion of details concerning foodstuffs more or less peculiar to warm climates (Chapters XII and XIII) ; (3) a description of diets suitable for hospitals, prisons and other institutions and for labourers at large ; (4) the increase in size of Chapters XVI

and XVII on public health activities in relation to nutrition ; (5) the inclusion of Chapters XVIII and XX on food poisoning and insect pests of grain foods respectively.

The great progress in parasitology and the later discoveries concerning nutrition fall into two great phases which have led, and are leading, to an improvement on the health of the masses in tropical countries. And this must continue with the growing acceptance that all persons have a right to diets adequate for good growth and health, as in another sphere it has long been accepted that all children have a right to primary education.

The lowering of the death rates, especially infantile mortality, is producing such an increase in the numbers of the populations of the tropics that one may wonder what will be the nature of the end of it, for an end there must be.

It is far more desirable that the knowledge and means for better nutrition should lead to an improvement in the quality of the individuals of the masses rather than to a great increase in the density of populations.

L. N.

COLOMBO,
January, 1945.

PREFACE TO FIRST EDITION

THE subject of nutrition has come very much to the fore in temperate climates and is having far-reaching results in respect of the growth of the children and the general health of the public. The great strides made in parasitology in its numerous branches absorbed most attention in Tropical Medicine, and only extreme conditions which arise from various food deficiencies such as beriberi, scurvy, pellagra and keratomalacia received much notice until very recently.

In the last few years much nutritional work has been done in several tropical countries and this has been mainly along two lines : firstly, the study of the less cogent results of dietary deficiencies has brought to light the prevalence of many signs, symptoms, stunted growth and other effects ; secondly, attention has been paid to the diets in use among general populations and large numbers of foodstuffs have been chemically analysed and biologically assayed.

The results of these investigations are recorded in many reports and papers.

The object of this book is to give, as shortly as possible, the general principles of nutrition and dietetics and to collect under one cover the salient points of this scattered information.

The book is meant primarily for medical men who work among the masses in the tropics.

COLOMBO, L. N.
February, 1938.

CONTENTS

CHAP.		PAGE
I.	CARBOHYDRATES, FATS AND PROTEINS	1
II.	MINERALS : CALCIUM AND PHOSPHORUS	24
III.	MINERALS (*contd.*) : IRON (ANÆMIAS), COPPER, MAGNESIUM, SULPHUR, MANGANESE. TRACE ELEMENTS, ACID-BASE BALANCE	39
IV.	VITAMINS : HISTORY, ANIMAL EXPERIMENTS	57
V.	VITAMINS (*contd.*) : VITAMIN A, VITAMIN B COMPLEX (THIAMINE)	73
VI.	VITAMIN B COMPLEX (*contd.*) : RIBOFLAVIN, PYRIDOXINE, PANTOTHENIC ACID, BIOTIN, PARA-AMINOBENZOIC ACID	101
VII.	VITAMINS (*contd.*) : VITAMIN C, VITAMIN D, VITAMIN E, VITAMIN K	121
VIII.	VITAMINS (*contd.*) : VITAMIN P (CITRIN), INOSITOL, CHOLINE, FOLIC ACID, POLYAVITAMINOSIS	147
IX.	CONDIMENTS, BEVERAGES AND "ROUGHAGE"	156
X.	ENERGY VALUE OF FOODS, STANDARD ALLOWANCES	163
XI.	ANALYSIS OF FOODSTUFFS	180
XII.	FOOD OF VEGETABLE ORIGIN : CEREALS, PULSES	203
XIII.	FOOD OF VEGETABLE ORIGIN (*contd.*) : ROOTS, VEGETABLES, NUTS, FRUITS	218
XIV.	FOOD OF ANIMAL ORIGIN : MEAT, FISH, SHELLFISH, MILK, MILK PRODUCTS, EGGS	233
XV.	DIETS FOR HOSPITALS, PRISONS AND OTHER INSTITUTIONS. LABOURERS' DIETS. INFANT FEEDING	250
XVI.	PUBLIC HEALTH ACTIVITIES IN RELATION TO NUTRITION. DIETARY SURVEYS, NUTRITIONAL SURVEYS	263
XVII.	PUBLIC HEALTH ACTIVITIES (*contd.*) : VITAL STATISTICS, PRACTICAL APPLICATION OF NUTRITIONAL KNOWLEDGE	283
XVIII.	FOOD POISONING	297
XIX.	INSECT PESTS OF CEREALS AND PULSES	321

APPENDICES

		PAGE
I.	The examination of the blood in anæmia	331
II.	The determination of vitamin A in livers by the antimony trichloride method	333
III.	Hess' capillary resistance test	334
IV.	Determination of vitamin C in the urine	335
V.	Dentition tables	336
VI.	Determination of prothrombin in blood	336
VII.	Atwater's bomb calorimeter	338
VIII.	A liquid extract of yeast for medicinal purposes	339
IX.	Instructions for dietary inquiries	340
X.	Average heights and weights of boys and girls	342
XI.	The A.C.H. index of nutrition	343
XII.	Nutritional section of a foodcraft exhibition	345
XIII.	Tests for H.C.N. in foodstuffs	353
XIV.	Determination of fluorine in water	354
XV.	The weight of the kernel in coconuts of various sizes	355
XVI.	Edible percentage of foodstuffs as bought in markets	356
XVII.	The weight of measured grain	357
XVIII.	Weights and measures	358
XIX.	Conversion graph—"Fahrenheit–centigrade"	359
XX.	Conversion graph—"Inches–centimetres"	360
XXI.	Conversion graph—"Ounces–grams"	360

LIST OF ILLUSTRATIONS

Graphs

PAGE

1. Indicating yearly iron needs for growth 46
2. Hopkins' graph of growth curves of rats 61
3. Vitamins removed with rice millings 209
4. Percentage of families having diets of various caloric values . 268
5. Heights of boys of different social status 271
6. Weights of boys of different social status 271
7. Weights of boys of different races compared . . . 273
8. Heights of boys of different races compared . . . 273
9. Heights of males and females compared 274
10. Weights of males and females compared 274
11. Weights of infants at birth of two social classes compared . 288
12. Weights of infants at birth of Ceylon and England compared . 288
13. Conversion graph—" Fahrenheit–centigrade " . . . 359
14. Conversion graph—" Inches–centimetres " 360
15. Conversion graph—" Ounces–grams " 360

Plates and Figures

1. Bitot's spots on pigmented conjunctiva 80
2. } Phrynoderma 82
3. }
4. Crystals of thiamine }
5. Crystals of riboflavin } 90
6. Pigeon with polyneuritis }

7. Angular stomatitis
8. Polyavitaminosis 103

9. Dog with rickets
10. Bone changes in rickets 134

11. Crazy pavement eruption
12. Nutritional œdema 153

13. Rice grains 203

14. Diagram of rice mill 208

15. Funnel and cone of a rice mill 208

16. Colocasia and dioscorea "yams" 220

17. Various edible leaves 223

18. Jak fruit and bread fruit trees 225

19. The sign of the median-dorsal furrow 275

20. Prickly Poppy (*Argemone mexicana*) 300

21. Achee fruit 302

22. Section of manioc root 302

23. Fluorotic teeth
24. Fluorosis of tibia 307

25. Rice Weevil (*Calandra oryzæ*) 322

26. The Lesser Weevil (*Rhizopertha dominica*) 322

27. The Pea Weevil (*Bruchus pisorum*) 324

28. The Common Flour Beetle (*Tribolium confusum*) 324

29. A Small Flour Beetle (*Orzæphilus surinamensis*) 324

30. Moths of granaries (*Corcyra cephalonica* and *Sitotraga cerealella*) . 324

31. Suction pump for testing capillary fragility 334

32. Atwater's bomb calorimeter 338

ERRATA

Page 10. Table V, first line :—*for* " CH " *read* " CH_3 "

Page 238. Lines 8 and 13 from bottom :—*for* " vitamin C." *read* " copper "

CHAPTER I

CARBOHYDRATES, FATS AND PROTEINS

A FOOD has been defined as "any substance which when taken into the body can be assimilated into the tissues for the purposes of growth, or the repair of waste, or to produce heat or work." But most diets contain beverages and condiments which cannot be comprehended in any simple definition.

The constituents of all foods are classified into the few categories given in Table I.

TABLE I

1. Carbohydrates 2. Fats	are used mainly as fuel for work or heat.
3. Proteins	nitrogenous substances necessary for building up the body and repair of tissues.
4. Minerals	necessary for growth and all metabolic processes.
5. Vitamins	occur in small quantities and are used for many, if not all, metabolic processes.
6. Beverages and Condiments	render the food more palatable, stimulate the appetite and digestion and have other effects.
7. Indigestible residue	insoluble and indigestible matter gives a necessary bulk to the food.
8. Water.	

Although the greater amounts of carbohydrates and fats are used for the production of work and heat, yet some of them are in combination with the proteins, and in small quantities are needed for the building of the tissues. Again, although proteins are used for the building of the body and the repair of tissues they can also be used as fuel for work and heat, and may be broken up in the body for the formation of carbohydrates and fats. The minerals have many functions and some of them form crystalloid-colloid complexes with the proteins of the blood and tissues. The vitamins have been called "accessory food factors," and they are essential for healthy metabolism.

CARBOHYDRATES

The carbohydrates comprise the sugars and starches and, being the cheapest sources of energy, constitute the greater part of the food of the populations of the world with the exception of a few pastoral and hunting tribes.

They are divided into three large groups and the names of these are derived from their general chemical formulæ :

$C_6H_{12}O_6$	Monosaccharides
$C_{12}H_{22}O_{11}$	Disaccharides
$(C_6H_{10}O_5)_x$	Polysaccharides

Monosaccharides

These simple sugars are soluble and diffuse through the walls of the alimentary tract without being acted upon by the digestive enzymes. The three commonest are glucose, fructose and galactose, and when they are consumed in larger quantities than are required for the immediate purposes of the body they are built up into the polysaccharide *glycogen*, which is stored in the liver and reconverted into glucose when required for the maintenance of the normal amount of sugar in the blood.

Glucose (*dextrose*, *grape sugar*, *starch sugar*, *corn sugar*) is of great importance in two respects—firstly, it is abundant in many fruits and other vegetable products, where it usually occurs in association with fructose and sucrose ; it may constitute 20 per cent. of the dried substance of grapes, and is present in many roots such as onions, sweet potatoes and yams ; secondly, it is the product of the action of the digestive enzymes on all starches. Glucose is oxidized to carbon dioxide in the production of energy and heat, but the action is not direct, intermediary bodies are formed.

Fructose (*fruit sugar*, *lævulose*) occurs in plant juices. It constitutes about half the sugar in honey. The body can convert it into glucose.

Galactose is formed together with glucose when the digestive enzymes act upon the dissaccharide lactose (milk sugar). The mammary gland forms galactose from glucose and then combines

it with more glucose to form lactose. The galactans which occur in many plants are polymeric anhydrides of galactose.

Glucose occurs in the tissues in combination with proteins.

Disaccharides

The disaccharides are changed into monosaccharides during the process of digestion. Three of them are important constituents of foods.

Saccharose (*sucrose, beet sugar, cane sugar*) is the commonest sugar in the markets of the world and is produced in enormous quantities from canes, palm trees, beetroot and maple. It occurs in most plant juices, usually in association with other sugars. Pineapples and carrots are particularly rich in it.

Saccharose rotates the plane of polarized light to the right, but the product of its hydrolysis, an equal quantity of glucose and fructose, rotates the plane to the left, this is because, although glucose is dextrorotatory, fructose is more actively lævorotatory. This inversion gives the name *invert sugar* to the product of the hydrolysis of saccharose.

Lactose constitutes 4 to 5 per cent. of the milk of cows and 6 to 7 per cent. of human milk. It is less soluble and less sweet than market sugar, and less likely to cause digestive disturbances in infants.

Maltose occurs in germinating cereals and the products of them, such as malt. When the digestive enzymes act upon starches maltose is formed as an intermediary product in the formation of glucose.

Polysaccharides

Most of the polysaccharides are insoluble in water, but some form colloidal dispersions which are usually opalescent, and a few form solutions. Those that are available for food are broken up by the digestive enzymes into glucose.

Starch is stored in plants, specially in seeds and tubers, as a source of supply for the future requirements of growth. The dried cereal grains contain from 50 to 80 per cent. of starch. When a small piece of a grain or tuber is broken up in a little water and examined under the microscope it is seen that the starch is stored

in dense granules ; if these are heated in water they rupture and the starch is dispersed. This is one of the changes brought about by cooking and enables the digestive enzymes to hydrolyse cooked starch more readily than when it is raw. One of the first actions of digestion is to break down the molecules of starch to less than a fifth of their size, and these products are soluble in water and are known as dextrins.

Glycogen is sometimes called animal starch. It forms an opalescent dispersion in cold water. It occurs in all parts of the body, and although under normal conditions the liver is richest in it, yet there are considerable amounts in the muscles, especially after periods of rest. It is rapidly used up during muscular exercise.

Celluloses. Plants are able to build up hard, resistant and insoluble polysaccharides, and these appear in wood and other structures in the form of fibres which consist mainly of cellulose. Other polysaccharides are of a softer nature and are known as hemicellulose. Some low forms of life are able to digest celluloses, but they have no nutritive value for man. They help to give bulk to the food and appear unchanged in the fæces.

FATS AND LIPOIDS

The fats and lipoids may be defined as substances which are soluble in ether, chloroform or benzene, but insoluble in water, and can be used as food by living organisms. The fats include all edible oils such as olive or coconut oil.

The fats are compounds of glycerol, which is trihydric, and fatty acids, which are monobasic, hence on hydrolysis the fats split up into three molecules of fatty acids and one of glycerol ; for example :

$$\underset{\substack{\text{palmitin}\\(\text{glycerol tripalmitate})}}{C_3H_5(C_{16}H_{31}O_2)_3} + 3H_2O \rightarrow \underset{\text{glycerol}}{C_3H_5(OH)_3} + \underset{\text{palmitic acid}}{3C_{16}H_{32}O_2}$$

The naturally occurring fats are made up of many triglycerides, but they are not all simple triglycerides in which a glycerol molecule is combined with three molecules of a single fatty acid ; in most cases it is combined with two or three different acids ; for

instance, a mixed glyceride having one molecule each of palmitic, stearic and oleic acid combined with one molecule of glycerol would be stearo-oleo-palmitin.

The fatty acids belong to a few homologous series and fall into two categories :

(1) *The Saturated Fatty Acids* have a formula $C_nH_{2n}O_2$, in which the number of hydrogen atoms is twice the number of carbon atoms. Table II gives the more important acids of this series and some of the fats in which they are found as glycerides.

TABLE II

Acids of the Series $C_nH_{2n}O_2$

Butyric acid, $CH_3(CH_2)_2COOH$	About 6 per cent. in butter.
Caproic acid, $CH_3(CH_2)_4COOH$	In butter and coconut oil.
Caprylic acid, $CH_3(CH_2)_6COOH$	In butter, human fat and vegetable oils.
Capric acid, $CH_3(CH_2)_8COOH$	In butter and coconut oil.
Lauric acid, $CH_3(CH_2)_{10}COOH$	In butter and all palm oils.
Myristic acid, $CH_3(CH_2)_{12}COOH$	In most animal and vegetable oils.
Palmitic acid, $CH_3(CH_2)_{14}COOH$	" " " "
Stearic acid, $CH_3(CH_2)_{16}COOH$	" " " "

The consistency of fats depends upon the molecular weights of their fatty acids. Butyric acid has a low molecular weight and the triglyceride of it is a thin oil, whereas the triglyceride of stearic acid of high molecular weight is a hard solid fat. Under ordinary temperature conditions in the tropics the last three fats of Table II are solid.

(2) *The Unsaturated Fatty Acids* are of several series and have general formulæ $C_nH_{2n-2}O_2$, $C_nH_{2n-4}O_2$, etc., in which the number of hydrogen atoms is less than double the number of carbon atoms.

Oleic acid, $C_{18}H_{34}O_2$, of the first series is the commonest unsaturated fatty acid in animal and vegetable oils. Erucic acid abundant in many vegetable oils also belongs to this series. The glycerides of the acids of the series $C_nH_{2n-4}O_2$, $C_nH_{2n-6}O_2$ and $C_nH_{2n-8}O_2$ are present in many fats. Linoleic acid, $C_{18}H_{32}O_2$, and linolenic, $C_{18}H_{30}O_2$, were first found in linseed oil, and later in butter and other fats. Sesame (gingelly) oil, a common edible oil of the tropics, contains 14 per cent. by weight of linoleic but

no linolenic acid. Arachidonic acid, $C_{20}H_{32}O_2$, of the fourth series occurs in brains, liver and egg yolks.

The unsaturated fatty acids can take up iodine (or other halogen) by addition to form saturated compounds. The amount of iodine taken up by a fat is more or less characteristic of that fat, and is known as the *iodine number*, and this number roughly indicates the amount of unsaturated fatty acid in the composition of the fat. The iodine number is the number of grams of iodine which can be taken up by 100 grams of the fat. Table III gives the iodine number of various fats.

TABLE III

Vegetable Oils

Oil	*Iodine number*	*Oil*	*Iodine number*
Linseed	175–205	Olive	79–88
Soya bean	137–141	Palm	20–56
Maize	113–125	Shea butter	56
Cotton seed	108–110	"Margarine"	50
Sesame	103–108	Chinese "tallow"	30
Pea nut	83–110	Coconut	9
Castor	83–86		

Animal Fats

Fish oils	120–195	Lard	60–70
Blubber oils (whale, seal)	100–150	Butter	26–28
Marrow fat	50–80		

Most of the glycerides of the unsaturated fatty acids have much lower melting points than the glycerides of the saturated fatty acids having the same number of carbon atoms.

The fat is firmer in land animals than in those of the sea, which is well illustrated by comparing lard with whale oil.

Soft fats or oils, which are rich in unsaturated fatty acids, can be hardened to a desired consistency by hydrogenation by which they are saturated with hydrogen by the aid of a catalyst, such as powdered nickel. This process has been widely used for the production of *margarine* and lard substitutes from vegetable and whale oils. These sophisticated fats have been used in vast quantities without ill effects arising from them and therefore may be considered wholesome. (Sometimes margarines are reinforced with fat soluble vitamins A and D.)

Human Needs for Fat. Fats are deposited in the subcutaneous tissue as a protection against cold and injury, and in the abdomen as a padding and support of the viscera. Their light, compact and insoluble nature enables the storage of them to take place without the addition of water, and this can occur with no other substance. The fats are composed of the same three elements as the carbohydrates, but they are superior to them as a supply of energy because they have less oxygen in proportion to the carbon and hydrogen, and hence on complete combustion produce more energy. Any normal deposit of fat is a reserve store for the production of heat and work.

It may appear obvious from many common experiences that fats can be synthetized from carbohydrates in the animal body, such as when pigs are fattened for the market by feeding them on grain meals rich in carbohydrates and poor in fats ; yet the matter was in dispute until it was settled by carefully planned experiments in which animals were fed on diets containing very little fat, showed that more fat was deposited in the body than was taken in with the diet. Other experiments have shown that carbohydrates contribute to the production of fat in milk.

Although much of the fat in the body may be formed from carbohydrates, yet fat is needed in the diet for several reasons, two of which are clearly understood. Firstly, certain essentials, such as vitamins A, D and E, can be adequately absorbed only when dissolved in fats. Secondly, there are unsaturated fatty acids, essential for healthy nutrition, which cannot be produced from carbohydrates. Burr and Burr,[1] in 1929, were the first to show that rats fed on fat-free diets became ill with staring coats, dermatitis, caudal necrosis and wasting leading to death. Later (1932) [2] they found that it was the unsaturated acids, such as linoleic and linolenic, which were essential. Their work has been amply confirmed. There is some evidence that arachidonic acid is the most important, and it may be that the two acids mentioned above are converted into it within the body. These acids act in very small amounts, one drop (0·1 gm.) of linoleic acid daily is sufficient for the growth and health of a rat. There is some evidence that these unsaturated

[1] *J. Biol. Chem.*, 82, 345.

[2] *Ibid.*, 97, 1.

fatty acids have a double action, because another fatty acid, docosahexænoic of cod-liver oil in small daily doses (0·1 gm.) will allow normal growth to return to rats which have been on fat-free diets, but it will not cure the dermatitis.[1]

The daily amounts of the unsaturated fatty acids needed are so small as to render it unlikely that they will be deficient in any human diet.

The vitamin pyridoxine (q.v.) appears to play a part in the absorption of the fatty acids.

The body fat of each species of animal is more or less of its own kind and is not materially affected by the usual diet. But when an animal is heavily fed on one particular kind of fat, some is stored in the adipose tissues in a proportion not normal to the animal.

LIPOIDS

The lipoids fall into three groups :

(1) *Sterols*, composed of neutral esters of alcohols combined with fatty acids ; cholesterol and ergosterol are examples.

(2) *Phospholipides* are compounds of an alcohol, fatty acids, phosphoric acid and an organic base (choline) ; lecithin is an example.

(3) *Glycolipides* are compounds of a carbohydrate (galactose), with a fatty acid and an organic base.

Lipoids are present in all cells and take part in many complex metabolic processes.

Ergosterol after irradiation with ultra-violet light has the physiological activities of vitamin D (q.v.).

Cholesterol is needed for blood formation. Chatterjee [2] has recorded that in an anæmia of pregnancy in women of India the amount of the esters of cholesterol in the blood is less than half of normal (78 and 30·8 mg. per 100 gm.), and that the anæmia can be rapidly cured by injecting 2 ml. of 5 per cent. cholesterol in olive oil parenterally every other day. This small amount of cholesterol would not correct the deficiency, and the lipoid can be synthetized in the body from oleic acid, therefore Chatterjee's results are difficult to understand.

[1] E. M. Hume, *Biochem. J.*, 32, 2162.

[2] *Lancet* (1940), 238, 14.

THE PROTEINS

The carbohydrates and fats are sources of energy for the muscular activities of the body and are used only in small amounts in the building of the tissues ; the proteins, on the other hand, are the main constituents of the cells of the body and form the greater part of the dried substance of the organs and muscles. All proteins contain the five elements nitrogen, carbon, hydrogen, oxygen and sulphur.

Chemical Nature of the Proteins

An analogy between the starches and the proteins may be suggested ; when the former are hydrolysed the large molecules break up and form dextrins and these break up into the disaccharide maltose which in turn becomes the monosaccharide glucose. The proteins on hydrolysis or digestion likewise produce substances of progressively smaller molecular weights, proteoses are first formed, then peptones and peptides, and finally amino-acids. The results of the hydrolysis of the two groups of substances is shown as follows :

Starches→dextrins→maltose→glucose
Proteins→proteoses→peptones→peptides→animo-acids

There is, however, one great difference : whereas the starches are all broken up into the single substance glucose, the proteins are broken up into a number of different animo-acids.

There are twenty-two animo-acids and it is possible that others, occurring in small quantities in proteins, remain to be discovered. The amino-acids, therefore, are the bricks with which the proteins are built, and the possible combinations and permutations of them in various quantities allow an almost infinite number of proteins to be built up from them, and it is not surprising that all forms of life have characteristic proteins.

The animo-acids are all compounds of the amino group (NH_2) with various organic acids, and they are classified according to the number and arrangement of the amino (NH_2) and carboxyl (COOH) groups which they contain. Table IV gives the classification with examples.

TABLE IV

Classification of the Amino-acids

Group I : *Monoamino-monocarboxylic acids*

Examples : Glycine, aminoacetic acid $CH_2(NH_2).COOH$.
Alanine, aminopropionic acid $CH_3.CH(NH_2).COOH$.

Group II : *Monoamino-dicarboxylic acids*

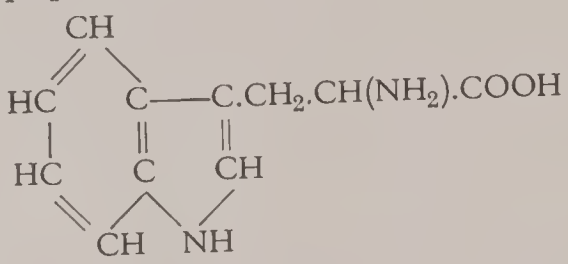
Example : Aspartic acid, aminosuccinic acid $COOH.CH_2.CH(NH_2).COOH$.

Group III : *Diamino-monocarboxylic acids*

Example : Lysine, diaminocaproic acid
$CH_2(NH_2).CH_2.CH_2.CH_2.CH(NH_2).COOH$.

Group IV : *Heterocyclic amino-acids*

Example : Tryptophane, indol alanine



Seven of the amino-acids are compounds of proprionic acid and the simplest of these is alanine, which is of great importance because the other six may be derived from it by the substitution of a simple or complex radical for one of the hydrogen atoms of the β-carbon

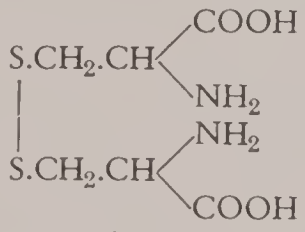
TABLE V

	(hydroxyl)	(sulphydryl)	(phenyl)
CH	CH_2OH	CH_2SH	$CH_2C_6H_5$
$CHNH_2$	$CHNH_2$	$CHNH_2$	$CHNH_2$
COOH	COOH	COOH	COOH
Alanine	Serine	Cysteine	Phenylalanin

(hydroxyphenyl)	(imidazole)	(indol)
$CH_2C_6H_4OH$	$CH_2C_3H_3N_2$	$CH_2C_8H_6N$
$CHNH_2$	$CHNH_2$	$CHNH_2$
COOH	COOH	COOH
Tyrosin	Histidine	Tryptophane

of the alanine molecule. Thus by the substitution of an OH or SH group serine and crysteine respectively is obtained, and similarly an indol radical produces tryptophane. Table V gives the seven "propionic" amino-acids and shows the substituted radicals.

Two molecules of cysteine are bound together to form dicysteine, usually called cystine, as in the following formula :

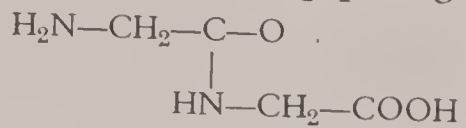


Cystine

Building the Proteins

The proteins have very high molecular weights, and the minimum which has been suggested is about 1,600, but most of them have far higher molecular weights than this.

Two amino-acids can combine by the carboxyl group of one reacting with the amino group of another with the elimination of a molecule of water, this can take place between two molecules of one amino-acid. The following formula shows the linkage of two molecules of glycin to form the dipeptide glycylglycin :



In this way a vast number of dipeptides, tripeptides and polypeptides can be formed, and this type of anhydration is the principal reaction by which the proteins are built up by the action of enzymes on the amino-acids formed by digestion. There are other substances in proteins as well as amino-acids, such as iron in hæmoglobin, phosphorous in milk and egg proteins, and the carbohydrates mannose and galactose enter into the composition of many proteins.

The Proportion of Amino-acids present in Various Proteins

There are many difficulties in the analyses of proteins for the determination of the amounts of the various amino-acids which they contain, and no analyses have yet been produced which are

entirely satisfactory. But the results are sufficient to show that some proteins are rich in some amino-acids and poor in others, and there are proteins such as zein of maize and gelatin which do not contain even a trace of one or more important amino-acids. Table VI shows roughly the great variations in the proportions of some of the amino-acids of four proteins.

TABLE VI

Percentage of Amino-acids found in Four Proteins

	Casein of milk	*Gliadin of wheat*	*Zein of maize*	*Gelatin*
Glycine	0·5	0·5	none	25·0
Alanine	2·0	2·0	10·0	9·0
Leucine	10·0	6·5	25·0	7·0
Proline	8·0	13·0	9·0	9·5
Phenylalanine	4·0	2·5	7·5	1·5
Glutamic acid	22·0	44·0	31·0	6·0
Hydroxyglutamic acid	10·5	2·5	2·5	none
Aspartic acid	4·0	0·8	2·0	3·5
Tyrosine	6·5	3·5	6·0	trace
Cystine	0·5	2·0	1·0	0·5
Histidine	2·0	3·5	1·0	1·0
Lysine	6·0	1·0	none	6·0
Tryptophane	2·0	1·0	none	none

The Nutritive Value of Proteins

The nutritive value of proteins depends mainly upon the kinds and proportions of their amino-acids. Much work has been done on this subject by Dr. L. B. Mendel and others, and their experiments have consisted in feeding young rats on diets containing a sufficiency of carbohydrates, fats, minerals and vitamins, but only a single protein, and if the rats fail to grow the diet is supplemented with one or more amino-acids which are deficient in the protein. As recorded in Table VI zein contains no glycine, lysine or tryptophane, and when young rats are fed on a diet sufficient in all respects except that zein is the only protein present they cease to grow, become ill, and do not survive long. If, however, lysine and tryptophane are added to the diets before the rats are moribund, health returns and soon they commence to grow. The addition of glycine has little or no effect. It is concluded

from this that lysine and tryptophane are essential in animal diets, but that glycine can be formed in the body, probably from the other amino-acids of the food.

Experiments of this kind have shown that the amino-acids which are essential in the food of the rat are—lysine, tryptophane, histidine, valine, cystine, methionine, phenylalanine, leucine, isoleucine and threonine. It is probable that what applies to the rat also applies for other animals. The matter, however, is relative ; glutamic acid, proline, arginine and others can be synthesized in the animal body, but they cannot be produced fast enough for the needs of normal growth and hence are necessary for the young. Cystine and methionine are the two amino-acids which contain sulphur, and the latter can replace or be changed into the former in the animal body, and although most of the requirements for cystine may be met in this way, yet there is some evidence that cystine is essential. Therefore some amino-acids cannot be placed in lists of two hard-and-fast categories—the essential and the non-essential.

For the purposes of showing relative values of proteins they have been grouped into three categories :

(1) " Complete." When one of these is the only protein in the diet and is present in sufficient quantity it can maintain life and support normal growth of the young. Casein and lactalbumin of milk, ovalbumin of eggs, glicinin of soya bean and glutelin of maize are examples of these.

(2) " Partially incomplete." These can maintain life but cannot support normal growth. Gliadin of wheat, hordein of barley and prolamin of rye are examples.

(3) " Incomplete." These are incapable of maintaining life or supporting growth. Zein of maize and gelatin are notable examples.

Here again the matter is very relative, casein is a fairly good protein, but it can support normal growth only when it constitutes about 18 per cent. of the diet ; in smaller quantities it must be supplemented with cystine, because it is poor in this amino-acid.

These studies are of great interest but they have very little practical importance in human diets mainly because all naturally occurring foodstuffs contain more than one protein.

Human Protein Requirements may be considered under two headings :

(1) For maintenance and growth ; (2) during pregnancy and lactation.

Protein Requirements for Maintenance and Growth

The body requires proteins for the repair of tissues, and to a small extent for the production of metabolic and digestive enzymes, also the hormones, such as thyroxin and insulin, are formed from amino-acids.

The wear and tear of the body in normal health does not result in the breaking up of very large amounts of nitrogenous matter. The muscles use carbohydrates for the production of work and heat as a steam engine uses fuel ; but this is not an exact comparison because an engine converts heat into work which is not done in the body, yet it serves to point to the fact that the muscles when doing work are using carbohydrates and are breaking down their proteins only to a very small extent.

It has been determined experimentally that about 3 gm. of nitrogen daily represents the specific endogenous expenditure of a man weighing 70 kg. (154 lb.). There is on an average 1 gm. of nitrogen in 6·25 gm. of tissue protein, therefore theoretically a man requires daily about 18·75 gm. of protein for the maintenance of the body. But there are many factors which render such an amount far too low for dietary needs, and among these are :

(1) *Katabolism* is not complete on a low protein consumption, and therefore the theoretical requirements are not sufficient for specific nitrogenous needs.

(2) *Digestive Utilization.* The proteins of various foodstuffs are not equally digested and absorbed, and the *coffiecient of digestive utilization* is the term used to express the ratio between the amount ingested and the amount absorbed. This is determined by the following formula :

$$\frac{\text{Ingested nitrogen} - \text{Fæcal nitrogen}}{\text{Ingested nitrogen}} \times 100$$

The coefficient of digestive utilization of meat, fish and milk is usually over 90, whereas products of vegetable origin range from about 60 for some dried pulses to about 90 for refined cereal flour. The refined flours are more digestible than wholemeal flours ; for instance, in an experiment on pigs the proteins of refined maize flour were digested to the extent of 94 per cent. compared with 71·4 per cent. for whole maize flour. These differences are obviously not due to any differences in the proteins but to the amount of cellulose and other inert matter which protects the proteins from the actions of the digestive juices.

Mixtures of food give far better utilization than foodstuffs taken singly, thus in five experiments on exclusive bread diet the average absorption of protein was 82 per cent., and on exclusive milk diet it was 92 per cent., but on a mixture of bread and milk it rose to 97 per cent.

Although a person can pass from one type of diet to another without serious results, yet usually he is able to digest the proteins of the diet to which he is accustomed better than those of a diet strange to him. This is one of the reasons of dietary conservatism.

(3) *Biological Value.* If the proteins of a diet contained all the amino-acids *in the same proportions* as they occur in the tissues of the human body, then they might be completely utilized and no part of them wasted. Whilst all the protein mixtures of most natural foodstuffs, whether of animal or vegetable origin, can provide for maintenance of the human adult, yet the amino-acids never tally so closely with the needs of the body that they can be used to the extent of 100 per cent. except possibly in the case of cannibalism.

The biological value is the term used to express numerically the ability of a protein to satisfy the nitrogenous needs for maintenance.

The following formula has been used to compute this value :

$$\frac{\text{Body N spared}}{\text{Food N absorbed}} \times 100$$

The biological value depends to some extent on the amount of protein in the diet. When there is 10 per cent. or more of protein in the diet, beef, mutton, pork, fish, eggs and milk have a biological

value above 90, shell fish (crabs, etc.) are lower, having a value of about 70. The proteins of the cereals range from about 60 to 80, those of roots (potatoes) from 60 to 70 and those of pulses are lower with 40 to 60.

Here again the proteins of mixtures of foodstuffs have higher biological value than the proteins of foodstuffs taken singly.

Although the quality of a protein for body maintenance can be expressed roughly in numerical terms, this cannot be satisfactorily done for growth, because the relative requirements for growth and maintenance are continually changing, and further, a protein which is of poor value in the early years of life may become more valuable in the later years when the growth requirements are declining and the needs of maintenance are increasing.

The maintenance requirements of children of all ages, except for a short period after birth, greatly exceed the growth requirements. Table VII gives these requirements at different ages :

TABLE VII

Body Protein Requirements of the Child During Growth

Age	*Weight* kg.	*Proteins required for*		*Total daily protein requirements*
		Maintenance	*Growth*	
At birth . .	3	2·5	2·3	4·8
„ 4 years .	15	5·3	1·28	6·58
„ 8 „ .	24	7·8	1·54	9·34
„ 14 „ .	42	13·1	3·33	16·43
„ 18 „ .	60	17·8	1·28	19·08

It follows that experiments with children for the determination of protein values for growth will have little value because the maintenance requirements will mask those of growth. It is very different with the young of most animals, which grow far more rapidly than children. A human being increases in weight from 12 to 65 kg. between the ages of 2 and 20, whereas a pig on a suitable diet will increase in weight 1 kg. a day. Thus whilst the pig is gaining 53 kg. in 53 days, man takes 18 years for a similar increase. This represents 187 gm. a day for a pig in contrast with 1·5 gm. for man.

The differences for the human being, the pig and the rat for

maintenance and growth are compared in Table VIII for the periods of their most rapid growth.

TABLE VIII

Period of growth	Mean weight kg.	Daily production of body proteins		Daily total gm.	Daily production of proteins in kilogramme body weight gm.
		Maintenance gm.	Growth gm.		
Human being 14 to 16 years .	48·5	15	3·33	18·33	0·38
Pig of 48 kg. .	48·0	15	189·00	202·00	4·20
Rat of 40 to 180 gm. . . .	0·11	0·06	0·33	0·38	3·20

In experiments with the growing pig or rat the maintenance requirements will not greatly mask the growth requirements.

Three experimental methods have been used to determine the relative values of different food proteins for growth.

(A) The determination of the minimum amounts of various protein foods which will support normal growth. Table IX gives the results of one of these experiments :

TABLE IX

The Minimum Protein Content of the Diet which Supports Normal Growth of the Rat

Foods of Animal Origin	*per cent.*	*Foods of Vegetable Origin*	*per cent.*
Milk	6	Whole wheat . .	10
Beef	9	Total rice proteins .	16–17
Liver	9	,, maize proteins .	17
Kidney	9	,, barley proteins .	17
		Pea flour . . .	18

(B) Batches of young rats of approximately equal weight are fed on diets containing 10 per cent. of proteins, but the diet for each batch contains a different protein food. The rats are weighed after 30 days and the averages are compared. Table X gives the results from such experiments.

TABLE X

Weight Increment in Grammes per Gramme of Daily Protein intake in Rats over a period of 30 days

Foods of Animal Origin		*Foods of Vegetable Origin*	
Milk	2·89	Wheaten flour	0·88
Beef muscle	3·15	Wheat (whole grain)	1·4
Ox liver	2·82	Rice (whole grain)	1–1·6
Ox heart	2·11	Oats (whole grain)	1–1·5
Pig's liver	3·54	Barley (whole grain)	1·2–1·9
Ox kidney	3·00		

(C) The third method is to supply diets which differ only in proteins they contain and are adequate in all other respects, and to calculate the coefficient of nitrogen retention according to the following formula :

$$\frac{(\text{N intake} - \text{fæcal N}) - \text{urine N}}{\text{N intake} - \text{fæcal N}} \times 100$$

Rapidly growing animals, such as young pigs, are used in these experiments because their maintenance needs are very small and do not greatly mask the requirements for their growth. Table XI gives the coefficient obtained from these experiments for various foodstuffs.

TABLE XI

Coefficient of Nitrogen Retention in Young Pigs

	Coefficient :	
	Absolute	*Relative*
Milk	67·6	100
Beef	49·5	77
Cereals		
Barley meal	41·3	65·9
Whole wheat flour	34·6	51·6
Whole maize flour	36·5	54·2
Whole oat flour	26·9	44·1
Pulses		
Soya flour	51·6	70·6
Pea flour	40·6	55·2
Lentil flour	25·6	38·3
Bean flour	25·3	35·4

Although these three methods do not separate the maintenance from the growth-promoting values of the various proteins for the growing animals, yet they are sufficiently indicative for the purposes of the dietition who is concerned with total results.

It will be seen that although the values vary somewhat according to the method pursued, yet the order of sequence is much the same in all cases. The most important conclusion is that the proteins of animal origin have a marked superiority over the proteins of vegetable origin ; and among the former milk holds an unrivalled place for promoting growth.

The Protein Requirement of Pregnancy and Lactation

The hypothetical needs of a pregnant woman can be easily estimated. A woman weighing 60 kg. (132 lb.) has a specific endogenous expenditure for maintenance of 2·8 gm. of nitrogen, and this multiplied by 6·25 gives 17·5 gm. of protein. The fœtus and adnexa contain on an average 100 gm. of nitrogen, most of this is in the form of protein, and may be considered as 625 gm. of protein. This amount is built up in 270 days of pregnancy and thus the mean daily production is 2·3 gm. When this is added to the maintenance requirements the total is $17{\cdot}5+2{\cdot}3=19{\cdot}8$. But the protein needs are not evenly distributed over the period of pregnancy, less is required during the early months than during the latter months when the embryo is rapidly increasing in size.

A woman during pregnancy is able to store proteins and other constituents of food as a reserve against the greater demands made upon her during the period of lactation.

No direct information exists as to the relative values of various protein foods for the building up of the fœtus and adnexa ; but it is justifiable to argue from analogy with the growth of the young and conclude that the values for pregnancy are much the same, and that foodstuffs of animal origin, especially milk, should always appear in the diets of pregnant women.

The amount of milk secreted by nursing mothers varies considerably, but an average of 0·8 litres daily may be taken for the purpose of estimating protein requirements. A mother's milk contains about 16 gm. of protein per litre, and therefore $16\times 0{\cdot}8$

=13 gm. is the amount which must be synthesized. This added to maintenance requirements gives 17·5+13=30·5 gm. Thus there is a far greater demand for proteins for lactation than for pregnancy; but some of this demand occurs during the later months of pregnancy when reserves are stored and the mammary glands hypertrophy for future lactation. No doubt can exist that a nursing mother needs a liberal supply of proteins, and some of these should come from milk and other comestibles of animal origin.

Supplementing

It follows from what has already been stated that a diet should contain proteins from a variety of foodstuffs, so that all the amino acids may be present in adequate amounts and proportions. The various cereals such as wheat, rice and millets supplement one another, and some cereals are well supplemented by pulses and roots. The products of animal origin are particularly valuable in supplementing vegetable products especially for the needs of growth.

Effect of Cooking on Protein Values

The heat of roasting may lower the protein values, for instance, the protein of the brown crust of bread have a lower digestive utilization and biological value than the proteins of the interior of a loaf. These values are also diminished by prolonged cooking or re-cooking of foodstuffs; but proper culinary procedures affect protein values only to a very small extent.

Specific Dynamic Effect of Proteins

Proteins have a specific stimulating effect on the fasting metabolism, so that, if for each 100 calories basal metabolism meat giving 100 calories is consumed, the metabolism does not remain at 100 calories but rises by about 30 per cent. to 130 calories. Rubner called this the *Specific Dynamic Effect*. It has been suggested that proteins are stimulants of metabolism in a pharmacodynamic sense, that is, they cause a greater breaking down and building up than is physiologically necessary. But a more probable explanation of the effect is that it is the heat produced during chemical reaction, such as when the amino-acids are converted into urea. There is

also a low specific dynamic effect with carbohydrates (6 per cent.) and fats (4 per cent.) ; here again it is probably due to the heat from chemical action, such as when glucose is converted into glycogen.

The specific dynamic effect of proteins is used to maintain the temperature of the body and may be of considerable value in cold climates. On the other hand it contraindicates the excessive use in hot climates of foodstuffs rich in proteins. The popular statement that meat is " heating " has some scientific foundation.

The Amount of Protein in Diets

A study of the diets of various races shows that man can adapt himself to high or low protein diets ; the former are taken by hunting and pastoral tribes, and the latter by the labouring classes of many densely populated tropical countries such as those of southern and eastern Asia.

High Protein Diets. Some of the hill tribes of Asia, the Somalis, Masai, Eskimos, the Kinghiz and some of the Central and South American Indians are among those who consume 200–300 gm. or more of protein in each adult's daily diet. Many of these tribes have been extolled for fine physique, virility and capacity for endurance. The men of most of these tribes are undoubtedly well grown, but their capacity for endurance needs defining. They are able to undertake tasks calling for great vigour and effort over a few days or weeks, such as fighting, hunting or rounding up cattle, but these activities are followed by periods of prolonged rest ; they cannot endure the unremitting toil of the workers of an industrial or even agricultural civilization. It appears that proteins are unsuitable as the source of energy of prolonged work, possibly because of the products of their metabolism and the thermodynamic effect.

Many ailments have been attributed to meat or diets rich in proteins, and among these are nephritis, arteriosclerosis and high blood pressure. But the evidence for this is lacking, and it is known that the Eskimos and other flesh-eating tribes are not particularly prone to these conditions.

Low Protein Diets are mainly, though seldom entirely, vegetarian.

The foodstuffs of animal origin can be cooked in more seductive ways than those of vegetable origin, and the great majority of people find that diets are unattractive which do not contain fish, meat or dairy products. The foodstuffs of animal origin are relatively expensive, and consequently low protein diets occur mainly among the labouring classes in countries where the economic status is low. The children of these classes are not well-grown, and weaning them on vegetable proteins of low biological values may be one of the causes, but these diets have other defects than in protein values.

Low protein diets have been advocated by a few scientists and others ; the latter usually have dietary prejudices not acceptable to the majority, and among these are vegetarians. Therefore vegetarianism may be considered here.

Vegetarianism. True vegetarianism, in which all comestibles of animal origin including eggs and milk are excluded from the diet, may be good for men and women in the later decades of life when the metabolism of the body is slowing down. It is not a good type of diet for adults during their vigorous years of life ; and it must be condemned as bad for growing children and for women during the period of maternity. In many parts of the world it is nearly impossible to prescribe a diet of local vegetable foodstuffs which is adequate nutritionally, even apart from the proteins.

Apart from theoretical considerations the physically and mentally vigorous races of the world have not been vegetarians.

There are, however, people who are called " lacto-vegetarians," and there is no doubt that a vegetarian diet adequately supplemented with milk, butter and cheese is beyond exception.

Disease and the Protein Factor

Nutritional Œdema (Pl. VI, Fig. 12) arises in persons who receive over a considerable period of time an amount of protein insufficient to preserve nitrogen equilibrium. The condition has been produced experimentally in dogs, oxen and rats on a low protein intake. There is diminished serum protein characterized by a lowering of the albumin fraction, and this is held to be the direct cause of the œdema by lowering the oncometric pressure. But the subject is not understood fully, and all very low protein diets are

deficient in more respects than one. Epidemics of œdema occur under war conditions and follow semi-starvation diets consisting mainly of roots. Nutritional œdema is common among the children of indigent mothers who wean them on farinaceous gruels (*vide* p. 152).

Resistance to Disease, such as tuberculosis, is certainly lowered by poor diets, and this is due to many factors and there is no evidence that the proteins are of paramount importance.

Fever from whatever cause increases the metabolic processes of the body and the excretion of nitrogen compounds rises far above normal. This obviously indicates needs for high protein diets during prolonged fevers and during convalescence.

The Healing of Wounds of all kinds has been shown to increase the general protein metabolism of the body apparently to meet an enhanced metabolism needed for the reparative process. For example, a patient with a fractured bone lost 137 gm. of nitrogen in the course of ten days.

This loss of nitrogen has been shown to occur in varying degrees in fractures, dislocations, effusions into joints and surgical incisions.

Liver Damage and Proteins. Miller and Wipple [1] recorded that methionine can protect dogs against necrosis of the liver by chloroform. Himsworth and Glynn [2] have shown that rats given a low protein diet develop massive hepatic necrosis, and the degree of necrosis can be determined by the amount of protein in the diets. They use the term *trophopathic hepatitis* for liver damage due to deficient diets to distinguish it from *toxipathic hepatitis* produced by poisons such as chloroform or phosphorus. Beattie and Marshall [3] have recorded that methionine, or casein digest rich in methionine, will lessen the number of patients showing liver damage after the arsenical treatment of syphilis; also that infective hepatitis or even *icterus gravis* may be successfully treated with this amino acid. Cystine is of value because it is a sparer of methionine.

The healing of liver injury from chloroform poisoning is delayed on a diet poor in proteins.

(For dietary protein allowances, see Chapter IX.)

[1] *J. Exp. Med.* (1942), 76, 421.
[2] *Lancet* (1944), 1, 457.
[3] *Nature* (1944), 153, 525.

CHAPTER II

MINERALS : CALCIUM AND PHOSPHORUS

TABLE XII gives the approximate percentages of the minerals present in the adult human body :

TABLE XII

Mineral	*Percentage in body*	*Mineral*	*Percentage in body*
Calcium	1·5	Magnesium	0·05
Phosphorus	1·0	Iron	0·004
Potassium	0·35	Manganese	0·0003
Sulphur	0·25	Copper	0·0001
Sodium	0·15	Iodine	0·00004
Chlorine	0·15		

and there are traces of many others.

The eleven elements named in the list in Table XII together with cobalt and zinc have been proved to be essential for animal life. Fluorine may be needed for the healthy formation of skeletal structures. Other elements such as As, Al, Rb, Br, B, Si, Ba and Ni, which have been found in the body in trace amounts, may have physiological significance, or may be fortuitously in the body because they are commonly present in many foodstuffs, or have been breathed in with the dust of the air.

The needs of the body for minerals may be summarized under three general headings :

(1) They enter into the constitution of all tissues. In the case of bones and teeth they are present in large amounts for the purpose of giving hardness, rigidity and permanence.

(2) They are present as soluble salts in all the fluids of the body, where they maintain osmotic pressure and solvent powers ; they supply the necessary electrolytes for the actions of muscles and nerves ; the acids and alkalis of the tissues and the digestive and other secretions are compounds of them.

(3) They have specific actions and are present in all enzyme systems.

The mineral elements are not present in the human body in the same relative proportions at all ages of human life, and Table XIII [1] shows these variations.

TABLE XIII

	Body weight	Total ash	Percentage of total							
	kg.	gm.	Ca	Mg	Na	K	P	Cl	S	Total
Fœtus, 7 months .	1·16	30	23	0·8	8	7	14	10	6	69
Newborn . . .	3·00	85	24	0·7	5	5	14	5	6	60
Young adult . .	70·00	3,000	39	0·7	2	5	22	3	4	66
Middle-aged adult .	80·00	4,000	42	0·7	2	5	25	3	4	82

Sodium Chloride

Sodium chloride is the only salt which is widely used by mankind as a comestible in a more or less pure form obtained either as salt dried out of sea water or from deposits in mines. All the other salts needed by the body are supplied in the food.

A healthy man excretes daily from 20 to 30 gm. of minerals in the urine, and the average of 25 gm. in 1,500 c.c. contain the following constituents :

	Gm.		*Gm.*
Sodium chloride . .	15·0	Magnesium . .	0·5
Potassium . . .	3·3	Calcium . . .	0·3
Sulphuric acid . .	2·5	Other substances . .	0·2
Phosphoric acid . .	2·5	Iron	0·005
Ammonia . . .	0·7		

There are also varying amounts of minerals excreted in the fæces. Table XII shows that there is roughly $2\frac{1}{3}$ times more potassium than sodium in the human body, the proportion is much the same in all mammals. The preponderance of potassium in plants is much greater, and foodstuffs such as grain and roots (unless grown on soils exceptionally rich in sodium salts), contain on a rough average about five times as much potassium as sodium. For reasons not fully understood, potassium salts taken in the food increase the amount of sodium salts passed in the urine.

[1] *J. Amer. Med. Assoc.* (1942), 120, 35.

The above facts show the need for salt (sodium chloride) by those living on diets containing much foodstuffs from vegetable sources. The herbivorous animals likewise need salt, and seek mineral earths ; and places where these are in use are called salt licks, or they drink the muddy water of ponds or rock pools where during the dry season evaporation has concentrated the soluble salts. Carnivorous animals do not require salt nor do they seek it, a sufficient supply is obtained from the bodies of their prey. Similarly, hunting and pastoral tribes who live on meat and milk need very little salt, some of them do not use it, and others use it only in small amounts.

Hard work in tropical climates increases the requirements for salt because of the salt lost through the sweat glands during profuse sweating. Hard-working labourers benefit by being supplied with drinking water to which salt has been added to the amount of 0·5 per cent. or $\frac{3}{4}$ oz. per gallon.

In past ages some populations dwelling far from the sea may have suffered from a deficiency of salt, but with the advance of mechanical transport salt is brought cheaply to almost all mankind ; but there are still a few tribes living in the interior of continents who obtain salt from mineral earths or even the ashes of plants rich in sodium.

Potassium

The requirements for potassium are amply met in all diets.

Calcium and Phosphorus

Because these two minerals are intimately connected in bone formation and also in some physiological processes they will be considered together. Ninety-nine per cent. of the calcium of the body and 70 per cent. of the phosphorus are present in the bones and teeth. The formula $CaCO_3.nCa_3(PO_4)_2$, in which n is between 2 and 3, roughly represents the compounds of these minerals in the skeleton.

The amount of calcium in the plasma of the blood is about 10 mg. per cent. and the amount of phosphorus is about 5 mg.

The Effects on Animals of Diets Deficient in Calcium or Phosphorus

As might be expected, many of the effects of a diet deficient in calcium are referable to the skeletal structures ; and most of the existing knowledge of this has been acquired from studies of deficiencies in animals.

When rats are supplied with insufficient calcium the most notable effect is a stunting of growth due to subnormal development of the skeleton. In one experiment twin brother rats were used, one was placed on a diet of wheat, meat and milk and the other on wheat and meat only ; the former grew normally, but the latter was stunted and had very poor development of the skeleton. The relative amount of calcium in the two diets was approximately as 100 : 14. Rats on low calcium diets, especially when the Ca : P is very low, are not only stunted but the bones are soft and misshapen, and the various proportions of the bones of the skull are not the same as in normal rats.

The ratio of the amount of calcium to phosphorus in the diet is more important for some animals than for others. The horse is particularly susceptible to a low Ca : P ratio in the fodder. A disease at one time called Miller's disease, was first recognized among horses of millers who fed them on bran, which has a very low Ca : P ratio. The disease is now called osteoporosis, or osteodystrophia fibrosa, and is characterized by swollen and malformed bones which become very soft as the disease progresses, and leads to damaged joints and fractures. The disease occurs in several countries where a low calcium content of the soils is reflected in the fodders grown upon them. At one time horses could not be bred in Ceylon, except in a few areas, such as in the north of the island, where the soil lies on a miocene limestone ; and most imported horses sooner or later developed osteoporosis and had to be destroyed. Some carefully planned experiments by Sturgess and Crawford showed that when the Ca : P ratio was lower than 1 : 5, horses developed this disease ; and that the addition of bone meal to the horses' diets was a successful preventive measure.

Cattle, on the other hand, are very susceptible to a low phosphorus calcium ratio. *Pica* is the term used by veterinary surgeons

for the manifestations of a depraved appetite such as earth eating or bone chewing by cattle, and it is considered a sign of some mineral deficiency. Sir Arnold Theiler made some brilliant deductions when investigating the cause of a South African cattle disease, known as lamsiekte. He showed that the immediate cause of the disease is due to the toxins of the organism of botulism being absorbed from decaying bones chewed by cattle, the ultimate cause is a deficiency of phosphorus in the soil and hence in the fodders, leading to a phosphorus deficiency in cattle, and this induces the bone-chewing habit. A supply of phosphates placed in the drinking-water of the cattle resulted in the disappearance of the pica and lamsiekte, and a great improvement in the general nutrition of the cattle.

There are numerous interactions between the various constituents of a diet ; and a deficiency of one may affect the availability of another. Experiments on rats have shown that the absorption and utilization of iron is to some extent dependent on calcium, and that when the latter is deficient in a diet more of the former is needed to prevent anæmia. Other experiments have indicated that the biological value of the proteins in more or less vegetarian diets is markedly increased by the addition of calcium above the theoretical needs for growth and maintenance. If the indications of these experiments are applicable to the physiological economy of the human body, they are of great importance in respect of the diets of the masses of the tropics.

The retention of lead in the body and its detrimental effects may be counteracted by excess of dietary calcium.

The Effects on Human Beings of Diets Deficient in Calcium or Phosphorus

It must be confessed that the knowledge of the effects on human beings of deficiencies of these important minerals is very meagre indeed. Doubtless deficiencies of calcium or phosphorus, or both, or an unsuitable ratio between them may determine the onset of rickets or osteomalacia and accentuate the deformities of the bones, but it has never definitely been shown that such deficiencies or an unsuitable ratio have ever caused these diseases when there has been an adequate supply of vitamin D (q.v.) in the diets.

Growth. In many tropical countries the labouring classes are less in height and smaller in weight than the more favoured classes, and in most cases the calcium in their diets is much below the amounts recommended by present-day nutritionists. The bones of children; who had been living on calcium-deficient diets, have been found to be well formed, and to contain a normal amount of calcium. It appears probable that provided all other factors needed for growth, especially vitamin D, are adequately supplied, a deficiency of calcium or phosphorus in children limits the size of the bones but does not lead to malformation.

Decay of the Teeth. Dental caries is very common among the children of the labouring classes of the teeming masses of the East, and in many localities the deciduous teeth are more affected than the permanent. It may be that the cause is an inadequate supply of calcium. It is certainly not due to a lack of vitamin D. The diets of these children are defective in more than one respect, and often the most marked defect is an insufficiency of vitamin A, and it is likely that dental caries is not a single entity and is of multiple origin.

Convulsions appear in the mortality returns of many tropical countries as a common cause of death among infants. Most of these deaths are due to infections in which the convulsions of infants are analogous to the rigors of adults. But there are reasons to believe that some of the deaths are from tetany due to calcium deficiency, such as when the seizures follow failure of the mother's milk and an attempt is made to rear the infant on a milk-free diet such as some cereal pap.

Irregularities of the Teeth.[1] Various forms of irregularities of the teeth of the fore-part of the jaws are common among the lower classes in countries where malnutrition is rife among the infants ; and similar irregularities are far less common among the wealthier classes. John Hunter pointed out that the part of the jaws which carries the deciduous teeth in infancy does not increase in length after the eruption of the deciduous teeth ; this has been amply confirmed in recent years. The deciduous teeth develop at the same time as that part of the jaws which carries them, and any stunting of growth from whatever cause may equally affect both the teeth

[1] See p. 103.

and the jaws. If in later life, when the permanent premolars, canines and incisors are developing to replace the milk teeth, the cause of the stunting is no longer present, the permanent teeth will be of normal size, but there will be insufficient space for their orderly alignment in the stunted part of the jaw which carries them, and malocclusions and irregularities of these teeth will arise. A similar disharmony of growth does not occur with the molar teeth, because they are growing *pari passu* with that part of the jaws in which they are embedded.

Pica among human beings has received less attention than it deserves, for the eating of earthy substances is fairly common in many parts of the world, particularly among children and pregnant women. It may be accepted that it is a sign of mineral deficiency, and that where the supply of common salt is ample the deficiency is probably of calcium or phosphorus or both. It can be corrected in some cases by supplying compressed cakes of refined calcined bone meal.

Factors Lessening the Absorption of Calcium

Firstly, a sufficiency of vitamin D (q.v.) is a necessity for the proper absorption of calcium from the alimentary tract and its maintenance in normal amounts in the blood ; and secondly, there are interactions among the constituents of the food which may affect the absorption of calcium by the formation of insoluble calcium compounds : in this respect two substances have received much attention—namely *oxalic and phytic acids.*

All foodstuffs contain *oxalic acid* but in most cases in quantities insufficient to affect greatly the absorption of calcium, but there are some foodstuffs such as spinach, green plantain and rhubarb which contain sufficient oxalic acid to combine with a considerable amount of the calcium in a diet. Majumdar and De [1] have analysed many Indian foodstuffs for their content of oxalic acid ; Table XIII gives their results in approximate whole numbers, also they have carried out certain experiments with rats and have shown that the retention of calcium and magnesium by rats fed on different cereals varies with the amount of oxalic acid in the particular cereal. Thus

[1] *Ind. J. Med. Res.*, 25, 671.

the retention of calcium in rice was 87 per cent. whereas when the millet ragi (*Eleusine coracana*) was substituted for rice the retention was only 43 per cent. (They do not appear to have taken into account the respective amounts of phytin in these cereals.)

TABLE XIII

Mgs. of Oxalic Acid per 100 gms.

Rice	5	Potato	15	French beans	31
Wheat	11	Colocasia yam	133	Spinach	660
Maize	10	Beetroot	40	Rhubarb	1,336
Ragi	46	Carrot	6	Cashew nut	318
Black gram	28	Green plantain	520	Tea leaves	219
Soya bean	77	Brinjal	29		

Phytic acid consists of one molecule of inositol linked with six phosphorus acid radicles; it forms insoluble compounds with calcium, magnesium and iron; it is present in considerable amounts in many cereals, but is more or less confined to the outer coats of the grain, and therefore wholemeal flour and lightly milled rice contain relatively large quantities compared with refined white flour or highly milled rice.

E. Mellanby showed that oatmeal was rachitogenic for puppies, and this was later proved to be due to phytin preventing the absorption of calcium. Krieger [1] and his co-workers have shown that the phosphorus of phytates is available for rats, and also that the calcium of Ca phytate is nearly as available for these animals as the calcium of chalk under the conditions of their experiments and provided there is ample vitamin D supplied.

A carnivorous animal, such as a dog, obtains its needed calcium from the bones and flesh it consumes; and it is not surprising that calcium combined in an insoluble form with the radicle phytic acid derived from vegetable matter is not available for a carnivorous animal, whose ancestors throughout the ages had never presented such a compound to their physiological economics. Rats, on the other hand, being omnivorous, have become adapted to the use of calcium phytate, probably because during past generations the food available for many of their forebears was grain containing much phytic acid.

[1] *J. Nut.*, 20, 7 and 15.

Ordinary white bread is made from flour of about 70 per cent. extraction, the germ and outer coats of the wheat grain is not included in this flour (*vide* p. 204). Because of the circumstances of war, bread of 92 per cent. extraction became compulsory in Great Britain, and although the latter contains more calcium than the former, it also contains far more phytates. When it was proposed to counteract the effects of phytin by the addition of chalk ($CaCO_3$) to this bread a voluminous disputation appeared upon the subject.

McCance and Widdowson [1] showed by balance experiments on a number of volunteers that there was a much smaller percentage of calcium absorbed from wholemeal bread (92 per cent. extraction) than from white bread (70 per cent. extraction). The volunteers belonged to the well-fed classes of England, and therefore had sufficient stores of calcium to last during the experiment; in any case the circumstances of the experiment did not produce the stresses needed for biological adaptation. The population of Great Britain obtains much of the necessary calcium from milk and cheese, where it is present in a very utilizable form; with the rationing of these and the introduction of wholemeal bread the available supply of calcium was lowered, therefore the addition of chalk to the bread was probably justified for the population of Great Britain.

Now the diets of the great majority of the teeming masses of Asia contain far less calcium and more phytin than the war-time diets of Great Britain, and it may follow that the addition of some calcium salt to these diets is desirable; but more research is required before this may be recommended, as it does not follow that, because well-fed Europeans cannot readily utilize the calcium of Ca phytate, the same applies to members of races accustomed to more or less vegetarian diets through many generations.

It has been shown that some of the phosphorus of phytates can be absorbed by man; and it has been suggested that calcium phytate is broken up in the lower part of the intestines by bacterial action, and that although the phosphorus compounds set free can be absorbed the calcium compounds cannot.

Table XIV gives in approximate whole numbers the phytin

[1] *J. of Physiol.* (1942), **101**, 44.

phosphorus as percentage of the total phosphorus present in some Indian foodstuffs as determined by Giri.[1]

TABLE XIV[2]

	Phytin P per cent. of total P		*Phytin P per cent. of total P*		*Phytin P per cent. of total P*
Barley	57	Wheat (whole)	60	Soya bean	33
Cambu millet	50	Wheat (75% ext.)	48	Nuts	38
Cholam millet	60	Bengal gram	60	Cashew nut	30
Maize	70	Black gram	41	Coconut	55
Ragi	70	Cow pea	35	Roots, leaves, vegetables and fruit have negligible quantities of phytin.	
Rice parboiled	54	Green gram	51		
Rice highly milled	23	Pea dried	31		
		Red gram	42		

(Phytin is present to the extent of 2 per cent. in wheat bran and 8 per cent. in rice bran.)

Magnesium forms an insoluble phytate, and although the affinity of calcium for phytic acid is a little greater, yet the two minerals share the acid fairly evenly between them and an increase of magnesium in the food will lead to a lessened formation of calcium phytate.

Fatty Acids. Under certain digestive disturbances, such as in diarrhœa in infants and sprue in adults, calcium combines with fatty acids and much insoluble calcium soap may be found in the fæces.

Factors Increasing the Absorption of Calcium

Although most attention has been paid to substances which diminish the absorption of calcium, yet there are factors which aid the absorption of the mineral from the intestines, such as the organic acids of fruit and vegetables. The banana has been shown to improve the absorption of calcium in rats.

Calcium Phosphorus Ratio. The adult does not require as high a Ca : P ratio as the growing child, because when bone formation has ceased more phosphorus is required than calcium for metabolic and excretory purposes. The optimum Ca : P ratios for human

[1] *Ind. Jour. Med. Res.*, 25, 869.
[2] For botanical names, see Chapter XI.

beings is not known, possibly it is about 1 : 2 for children and 1 : 3 for adults, but in some countries the ratios in the diets in common use is 1 : 5 or even lower.

The Determination of Calcium Requirements

Balance experiments are among the methods used in attempts to decide human requirements for calcium. Samples of all food prepared for consumption are analysed for the calcium content, and by weighing all the food before it is consumed the amount of calcium entering the alimentary tract is determined. The amount of calcium passed in the fæces and urine is also determined. If the amount of calcium in the food is greater than the amount excreted, then some calcium, which has been absorbed from the alimentary tract, must have been stored in the body and the person is in *positive balance* ; if, however, more is excreted than retained, the person is in *negative balance*. It may appear a simple matter to determine human requirements of calcium by balance experiments—the amount for a child of a particular age would be decided by the retention being just sufficient for good health and growth of a child of that age, and the needs of an adult would be considered to be the amount of calcium in the diet which just maintained the calcium balance in the body with very little retention. But biological processes do not conform to a simple fixed order ; there are fluctuations, compromises and adaptations, and hence balance experiments have many limitations and among these are :

(1) *Fluctuations*. An adult may be in negative balance for a long period, such as a number of months, followed by a short period of heavy storage of calcium ; or there may be day-to-day fluctuations. This suggests that in normal adult metabolism the calcium is being alternatively withdrawn from and returned to the skeleton.

(2) *Storage*. The walls of the cancellous spaces of the bones are well adapted for the storage of calcium, and in a well-fed person there is an ample supply always available, and changes in a diet by which a digestible form of calcium is replaced by a less digestible form may immediately be followed by a negative balance as the body takes the line of least resistance and falls back on the stores in the bones ready for its needs.

(3) *Biological Adaptation* may occur under stress, especially when small stresses have been present in many past generations, thus many tropical populations have become adapted to a low calcium intake. Balance experiments, carried out on well-fed persons, who are not subjected to stresses, such as depletion of the calcium reserves, are unlikely to be of great value for the determinations of the needs of the labouring classes of tropical populations.

The first consideration for growth, pregnancy and lactation is the amount of calcium needed to be retained in the body if these processes are to be healthily maintained. The amount of calcium laid down during growth can be determined approximately by drying and weighing the bones and teeth of skeletons of each sex and at each age of life and dividing the weights by four, about 25 per cent. of the weight of healthy dried bone being calcium.

Table XV is drawn up from a number of such determinations with male skeletons (*J. of Nut.*, 18, 563).

TABLE XV

Daily Calcium Retention needed by a Boy for Good Growth

Age	Body weight kg.	Ca in body gm.	Ca per kilo. body weight gm.	Increase in Ca during previous year gm.	Average daily retention of calcium gm.
1	9·5	105	10·0	(20)	0·055
2	12·0	126	10·5	21	0·057
3	14·0	150	11·0	24	0·065
4	15·5	180	11·5	30	0·082
5	18·1	217	12·0	37	0·10
6	20·2	253	12·5	37	0·10
7	22·6	294	13·0	41	0·11
8	25·0	338	13·5	44	0·12
9	27·4	384	14·0	46	0·12
10	30·6	437	14·5	53	0·14
11	32·6	489	15·0	52	0·14
12	34·8	539	15·5	50	0·13
13	37·4	598	16·0	59	0·16
14	41·7	688	16·5	90	0·24
15	46·6	792	17·0	104	0·28
16	54·0	918	17·0	126	0·34
17	59·4	1,010	17·0	92	0·25
18	65·0	1,105	17·0	95	0·26

The average weight of young working-class adults of tropical Asia is 50 and 44 kg. (110 and 96 lb.) for men and women respectively, and the amount of calcium in their skeletons is about 840 and 626 gm. respectively. The adults of the upper classes, however, are considerably larger. Table XV shows the calcium storage of a boy who reaches the weight of 65 kg. at the age of eighteen, this is far above the average weight for most tropical races. The skeleton increases in weight up to middle age to support the larger muscles, and a skeleton which contained 900 gm. of calcium at the age of twenty might contain 1,100 gm. or more at the age of forty. The addition of 200 gm. of calcium to the body over a period of twenty years needs a daily retention of such minute amounts of calcium that it may be neglected when considering calcium requirements.

The additional needs of calcium by a pregnant woman may be calculated from the additional calcium stored in the infant, placenta and for the increased weight which occurs with many mothers during pregnancy. The body of a healthy newborn infant of 7 lb. contains less than 20 gm. of calcium, the amount in the placenta and increased flesh of the woman varies greatly, but 10 gm. is an ample allowance for these.

Most of this 30 gm. of calcium is retained during the last five months of pregnancy, and this gives an average of 0·2 gm. daily.

A litre of human milk contains about 0·4 gm. of calcium, but the average lactating woman of tropical races does not produce as much as a litre of milk daily.

Various estimates have been made of the amount of calcium needed in a diet to meet satisfactorily the requirements of the body at different ages and during pregnancy and lactation. These estimates have been made for the peoples of temperate climates who are of a more robust build than the inhabitants of the tropics, but even for the conditions in the temperate climates these estimates appear unnecessarily high, and even if such quantities of calcium are optimum, which is doubtful, yet to recommend them for the masses of most tropical countries is economically impracticable unless the calcium is given in the form of a salt.

The daily diet of the average adult of southern Asia has a value of about 2,400 calories and children of five and ten years consume diets of a value of about 900 and 1,800 calories respectively, and the amount of calcium in the diets of these children is about 0·2 and 0·4 gm. respectively. However deficient such quantities of calcium may appear, the fact that the majority of children become adults shows that they make-shift to grow on these quantities.

The Committee on Food and Nutrition of the United States National Research Council recommended 1 gm. of calcium daily for children from the time " of weaning " to the age of ten years, and then an increase of 1·2 gm. and another increase to 1·4 gm. at the age of thirteen. An infant at the time of weaning is receiving a little less than 0·4 gm. from its mother's milk, and it appears unnecessary to increase this to 1 gm.

Table XVI gives suggested daily allowances for calcium; column I is the Author's estimate of the amounts sufficient for most agricultural tropical races for good health, column II gives the recommendations of the Committee on Food and Nutrition of the United States National Research Council.

TABLE XVI

	Column I (Author's)	*Column II (U.S.N.R.C.)*
	gm.	*gm.*
Child 1 to 7 years	0·5	1·0
„ 8 to 12 „	0·75	1·0–1·2
Adolescents 13–18	1·0	1·4
Adults . .	0·5–0·7	0·8
Pregnant women	0·8	1·5
Lactating women	1·0	2·0

The amount of phosphorus requirements is somewhat greater than the amount of those of calcium.

Nature has liberally supplied calcium and phosphorus in the milks of all species of animals, and there is an interesting parallelism between this supply and the rate of growth of their young. Table XVII records the fact that the infant grows less rapidly than the young of animals, and the quantities of calcium and other nutrients in the milks vary with the rate of growth of the sucklings.

TABLE XVII

Relation of the Composition of Milks with the Rates of Growth (after Bunge and Abderhalden)

Species	*Days required to double birth-weight*	*Percentage composition of milk*			
		Protein	*Ash*	*Calcium*	*Phosphorus*
Human . .	180	1·6	0·2	0·03	0·02
Horse . .	60	2·0	0·4	0·09	0·06
Cow . .	47	3·5	0·7	0·12	0·09
Goat . .	22	3·7	0·78	0·14	0·18
Sheep . .	15	4·9	0·84	0·18	0·11
Dog . .	9	7·4	1·33	0·32	0·22
Rabbits . .	6	14·4	2·50	0·65	0·43

A practical lesson to be learned from this is that the milk of cows or goats always contains a good supply of calcium and phosphorus for the growth of children. A pint of cow's milk, containing about 0·8 gm., incorporated in the daily diet will meet all calcium and phosphorus requirements.

CHAPTER III

MINERALS (*contd.*): IRON, COPPER, MAGNESIUM, SULPHUR, MANGANESE AND THE TRACE ELEMENTS; ACID-BASE BALANCE

Iron

There is in the body of an average adult a little less than 3 gm. of iron; and 70 per cent. of this is in the blood where it is an essential element for the formation of hæmoglobin of the red blood corpuscles. Iron is also present in the chromatin and other substances of the cells of the body.

Because iron is of such importance in the formation of the red blood corpuscles it will be convenient to consider here the common anæmias of the tropics.

Tropical Anæmias

Apart from iron there are other important factors needed for the formation of healthy red blood cells:

(*a*) Copper (q.v.) is necessary for the production of hæmoglobin although it does not enter into the hæmoglobin molecule.

(*b*) The factors suggested by the work of Minot and Murphy [1] on the blood regenerating power of various foods, and later clearly indicated by Castle and his colleagues.[2] These are (1) *an intrinsic factor* in the stomach and upper part of the intestine, which doubtless has enzyme action; and (2) *an extrinsic factor* present in most foodstuffs. The intrinsic factor converts the extrinsic into a substance needed for the building up of the red blood cells, some designation being needed this has been rather inappropriately called the P.A. (pernicious anæmia) factor.

(*c*) There is evidence that various other factors are needed for proper blood formation such as riboflavin, cobalt (q.v.) lipoids and certain amino-acids, but no clear-cut picture of

[1] *J. Amer. Med. Assoc.* (1926), 87, 470.
[2] *Am. Journ. Med. Sci.*, 178, 748; *Lancet* (1932), 1, 1198.

the interplay of these (and probably other factors) has yet been produced.

There is a popular opinion that the blood of inhabitants of tropical countries contains fewer red blood cells and less hæmoglobin than the blood of those living in temperate climates. Numerous investigations lend no support to this (*vide* Appendix I, p. 332).

The classification of the anæmias is based upon :

(*a*) The fall in the number of red blood cells from the normal amount per cmm.

(*b*) The change in the mean size of the red blood cells.

(*c*) The amount of hæmoglobin relative to the number of red blood cells (*vide* Appendix I, p. 332).

The following terms are used in the classification of the anæmias :

Orthochromic	Colour index is unity
Hyperchromic	,, ,, greater than unity
Hypochromic	,, ,, less than unity
Normocytic	Mean size of red cells is 7·2μ
Macrocytic	,, ,, ,, greater than 7·2μ
Microcytic	,, ,, ,, less than 7·2μ

When there is a shortage of iron (and sometimes copper) for the formation of adequate hæmoglobin, such as occurs after chronic hæmorrhages or red blood cell destruction, the red blood cells are deficient in hæmoglobin and the anæmia is *hypochromic* and usually *microcytic*.

On the other hand, when the factors needed for the formation of the stroma of the red blood cells are deficient and the iron is sufficient for ample hæmoglobin formation, then the anæmia is *hyperchromic* and usually *macrocytic*.

The " tropical and nutritional " anæmias may be provisionally listed as follows :

(A) *Hypochromic Microcytic Anæmias :*

(1) Chronic hæmorrhages.
(2) (Chlorosis).
(3) Common mild anæmias of women.
(4) Anæmia of infancy.
(5) Hookworm Anæmia.
(6) Malarial Anæmia.

(B) *Hyperchromic Macrocytic Anæmia :*
- (1) Pernicious Anæmia.
- (2) Macrocytic Tropical Anæmia.
- (3) The anæmias of pregnancy.
- (4) The anæmia of pellagra.
- (5) The anæmia of sprue.

(C) *A Combination of A and B :*
- (1) Some anæmias of women (especially those of pregnancy).
- (2) When there is a combination of factors such as hookworm infestation and those leading to macrocytic anæmia.

(A) *Hypochromic Microcytic Anæmias*

Chlorosis (idiopathic hypochromic anæmia) does not occur in the tropics. It was at one time common in Great Britain among factory and shop girls, and was mainly due to iron deficiency ; their diets were of the " white bread, margarine and tea " type, which in some cases did not contain more than about 1 mg. of available iron daily, and this was insufficient to make good the blood loss of the menses.

Common Mild Anæmias of Women. The women of the poorer classes in the tropics as in other parts of the world are far more often anæmic than the men, the diets of the former are apt to be poorer in quality and less in amount than those of the latter ; and the menses, pregnancy, lactation and the menopause increase a woman's need for iron.

Anæmia of Infancy. This is mainly due to iron deficiency. A child born of a healthy mother has a considerable reserve of iron and copper in the body. At birth the hæmoglobin level is well above 100 per cent. (as high as $19\frac{1}{2}$ gm. per 100 ml. of blood) and a red cell count of about 7 millions per cmm. ; a normal fall takes place to about 65 per cent. hæmoglobin by the 10th week, and then there is a rise which reaches 75 per cent. at the 5th–6th month of life. If the infant has been born of an anæmic mother and received inadequate reserves, or is weaned to cow's milk only, then a second fall occurs and the child passes into a state of definite anæmia.

Nature has failed to incorporate iron and copper in generous amounts in milk, and hence milk must be considered deficient in these elements. (A similar anæmia can be produced in dogs or rats by feeding them on milk exclusively. The anæmia is cured by giving iron and copper preparations with no other treatment, the milk being adequate as food for these animals in all other respects.)

Hookworm Anæmia (*Ankylostomiasis*) is similar to the anæmia following chronic hæmorrhages and is due to blood loss brought about by the hookworms in the small intestine. If the duodenum of a man or animal infested with one or other species of hookworm is examined *immediately* after death many of the worms will be seen to be red from the blood within them ; and further there may be a slight oozing of blood from small ecchymoses produced at the sites where worms have been attached and caused injury with their mouth parts.

Several investigators have removed worms from the intestines of dogs immediately after death and have kept them in moist chambers in incubators until the worms were free from blood. The worms were then weighed and placed in the intestine of an anæsthetised dog, they quickly took in blood and after a short time were removed and weighed again, the difference in the two weights gave the amount of blood taken in by the worms. These experiments have great limitations because they tell us nothing of how often the worms feed, or the differences between male and female requirement, nor do they reveal the blood loss from ecchymosis, hence the estimations of different observers have varied greatly, the extremes being from 0·1 to 1·0 gm. of blood consumed by or lost through the action of each worm daily. Even on the lower estimate a moderate infestation of 100 worms would bring about a blood loss of 10 gm. daily.

The dietary factor is all important. A well-fed dog given an adequate diet rich in iron may be infested with large numbers of worms without becoming anæmic, whereas an equal infestation of a badly fed dog will lead to severe anæmia.

It is the same with human beings, a moderate infestation with hookworms has little or no effect on the health of the well fed ; it

is the poor diets of the lower classes that make hookworm anæmia rife in many tropical lands.

Provided the diet is adequate the administration of iron will cure hookworm anæmia even without treatment to expel the worms. Indeed, it is the practice in some hospitals to treat debilitated patients, especially when they are young children, with good diet and iron until the anæmia has lessened and the general health has improved before giving potent antihelmenthics.

The Anæmia of Malaria. The parasites of malaria destroy the red blood cells and in forming pigment renders some of the iron not available for blood regeneration by the bone marrow. Some authorities consider that the infection and destruction of the red blood corpuscles by the parasite is insufficient to account for the degree of anæmia which occurs in malaria, and suggest the existence of a hæmolysin probably set free by the sporulating parasite. This may be the case, but the amount of infestation and hence the amount of destruction of red blood cells cannot be determined from the appearance of films of the peripheral blood. In quartan and tertian malaria many of the infected corpuscles are held up in the visceral organs, mainly the liver and spleen, and in the case of subtertian the retention is so great that the asexual parasite is seldom seen in the peripheral blood beyond the stage of the ring form.

(B) *Hyperchromic Macrocytic Anæmias*

Pernicious Anæmia was, before the discoveries mentioned on p. 39, a rapidly fatal disease, but now injections of liver extracts containing the P.A. factor, although they cannot recall a lost function of the stomach, yet they keep the disease in abeyance and may allow the afflicted to reach the allotted span of life.

Pernicious anæmia is very rare in the tropics, there are, however, anæmias which resemble it in that they are hyperchromic and macrocytic, but they are inherently of a less serious nature. Presumably these anæmias are due to some deficiency, other than of iron or copper. As these anæmias occur almost entirely among the poorest classes, it has naturally been suggested that they are due to a deficiency of the *extrinsic factor* in the diets, but this cannot be

proved until far more work has been done to reveal the nature of the *extrinsic factor*.

Hyperchromic macrocytic anæmia in its milder forms is not uncommon among both men and women of the indigent labouring classes of the tropics.

The Anæmias of Pregnancy. In many tropical countries, especially where there are dense populations, the anæmias of pregnancy are rife among the indigent classes and lead to high puerperal mortality rates, numerous stillbirths and the early death of many newborn infants from immaturity.

In many cases the anæmia is at first microcytic, but with the growth of the fœtus there is an ever-increasing drain from the mother of some factor or factors already deficient in her food, and the anæmia becomes macrocytic and hyperchromic. In its extreme form it has been called the " pernicious anæmia of pregnancy," and under this term it has been studied in India. Lucy Wills [1] tried the effects of various yeast preparations, and reported that marmite was curative, but yeast in other forms was not. Marmite is an antolysed salted preparation of yeast, and possibly antolysis has rendered some factor available. Other workers have not found marmite curative. Chatterjee [2] reported that this type of anæmia could be cured by the intramuscular injection of 2 ml. of 5 per cent. cholestrol in olive oil.

Napier [3] divides the anæmias of pregnancy into three types :

(*a*) A microcytic hypochromic anæmia due to a deficiency of iron in the diet or to continuous loss of blood most commonly from hookworm infestation.

(*b*) A macrocytic hyperchromic anæmia due to a deficiency in the diet of some substance present in marmite and in crude liver extracts (or campolon) but not in purified extracts (West and Drakin fraction, anahæmin).

(*c*) A macrocytic hyperchromic anæmia in which there is increased hæmolysis producing hyper-bilirubinæmia (a positive van der Bergh reaction) and a high reticulocype percentage associated with chronic malaria and defective diets.

[1] *Ind. J. Med. Res.*, XXI, 669. [2] *Lancet* (1940), 238, 14.
[3] *Ind. J. Med. Res.*, XXVII, 1009.

Napier also considers that there is a "conditioned toxæmia," conditioned because of defective diets.

The Anæmia of Pellagra is hyperchromic and macrocytic and may be due to a deficiency of the *extrinsic factor* from the diet or to failure to produce or absorb the *P.A. factor* by the degenerate alimentary tract.

The Anæmia of Sprue is also hyperchromic and macrocytic and is due to failure of the intestine to absorb the necessary factors for blood formation. The anæmias of pellagra and sprue can be cured by treatment with the indicated vitamins and injections of liver extracts.

(C) *Combined or Intermediate Types of Anæmia*

These appear to be due to the interplay of more than one deficiency. They may be orthochromic and normocytic, or, as has been mentioned under *anæmias of pregnancy*, the type may change from microcytic to macrocytic. The anæmia of hookworm or malaria may change to the macrocytic hyperchromic type, and when this occurs some deficiency in the diet is changing the primary character of the anæmia. Trowell[1] proposes the name *diphasic anæmia* for these types.

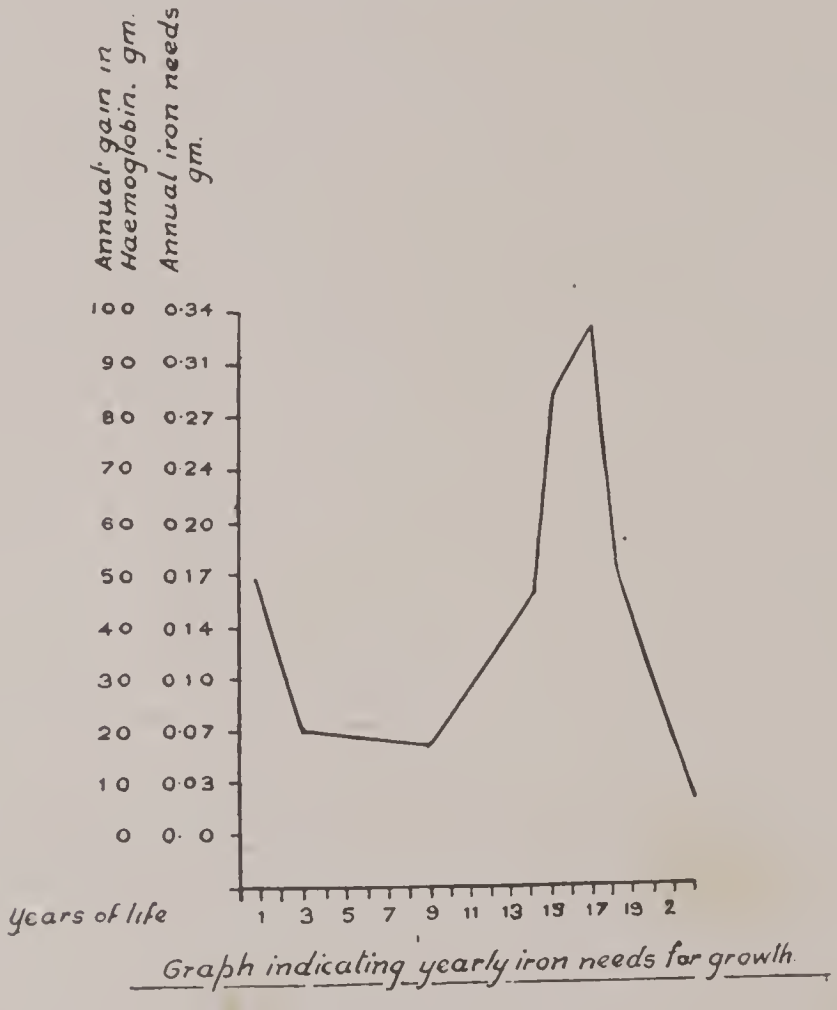
Requirements for Iron. The fundamental fact concerning iron is that it is an element and is not used up or destroyed in the body as occurs with vitamins. It is present only in traces in the urine and bile, and therefore it is not needed for excretory purposes as is the case with calcium, phosphorus and other elements. Further, the iron compounds set free when decrepit red blood cells are broken up in the spleen are retained and used again and again for the formation of young red blood cells in the bone marrow. It follows from this that the nutritional needs for iron are small and it is highly improbable that adult males ever suffer from anæmia primarily due to a shortage of iron in their diets.[2]

Women must make good the blood lost at the menses and meet the requirements of pregnancy and lactation, therefore their needs are greater. Children have needs for growth; during the first

[1] *Trans. Roy. Soc. Trop. Med. and Hyg.*, XXXVI, 151.

[2] Those desiring further information on the anæmias of the tropics should consult the "Hæmatological Studies" by L. E. Napier and his associates, which have been published in Vols. 22–27 of the *Ind. Jour. Med. Res.*

year of life there is a gain of nearly 50 gm. of hæmoglobin in the blood (or about 0·18 gm. of iron), this gain is far less during the next two years and by the fourth year is about 20 gm. of hæmoglobin, and this amount, or slightly less, continues to be needed yearly until the 9th year when rapid growth sets in, and then requirements continue to rise until during the 17th year the average



GRAPH 1

adult boy gains nearly 100 gm. of hæmoglobin (or about 0·35 gm. of iron), and thereafter there is a fall as he passes from adolescence to manhood. Girls have slightly smaller requirements until the start of catamenia, when it is estimated they lose about 0·3 gm. of iron yearly, and this must be added to their requirements for growth. Graph 1 shows roughly the yearly increase in iron in the body of an average male during each year of growth.

Much of the iron in some foodstuffs is contained in hæmatin-like

compounds which pass unchanged through the intestines, and therefore the iron is not nutritionally available. Hill reported that nutritionally available iron will react with dipyridyl in contrast to the unavailable iron which will not. The foodstuff is digested for $2\frac{1}{2}$ hours, sodium hyposulphite is added to reduce the iron, and on the addition of dipyridyl a coloured compound of iron develops, and comparison with a standard colour determines the amount of iron available. Hill's method appears to be satisfactory for the determination of available iron in the experimental diets of rats ; and is probably applicable to human dietaries.

The following amounts of iron in diets will amply meet human requirements even when as much as 40 per cent. of the iron is not available.

Age	*Mg. of iron*
Children 1–6	7
„ 7–12	10
Males over 12	12
Females over 12	15

It must be remembered that what may be termed " iron deficiency anæmias," such as from chronic hæmorrhages, hookworm infestation, etc., frequently arises when theoretically there appears to be ample iron in the diets. And these anæmias are readily curable by large doses of iron preparations which are out of all proportion to the theoretical requirements. Such doses for an adult as 5 gr. (0·3 gm.) of ferrous sulphate three times a day, or 20 gr. (1·3 gm.) of ferri et ammonium citrate three times a day are usually needed. The amount of iron taken therapeutically in a few days may exceed the amount normally present in the body of an adult of average size (3 gm.).

Large doses of iron cannot be given parenterally without poisonous effect, and small doses are valueless.

The Amount of Iron in Foodstuffs. This varies enormously even among different samples of the same foodstuff because to some extent the amount of iron in a plant is determined by the percentage of iron in the soil, for instance, the amount of iron in carrots may vary from 0·2 mg. per cent. to as much as 9·0 mg. per cent.

Consequently the amount of iron in foodstuffs can be given only

as rough averages in analytical tables; and the determination of the amount of iron in any particular diet by the use of such tables is more or less valueless.

Considered in terms of dry weight the richest sources of iron in the vegetable kingdom are green leaves, followed by fresh fruits and vegetables, and in the animal kingdom, beef juice and liver, followed by heart and kidney.

Table XVIII gives the average amounts of iron in various foodstuffs.

TABLE XVIII

Iron in Foodstuffs

FOODSTUFFS OF ANIMAL ORIGIN:

	mg. per cent.	*mg. per oz.*
Fish	1	0·3
Meat, Chicken	2	0·6
Beef juices	44	12·0
Heart, Kidney	4	1·2
Liver	7	2·0
Crab	15	4·0
Eggs	2	0·6
Egg yolk	8	2·3
Milk (cow's)	0·24	—
Milk (human)	0·15	—

FOODSTUFFS OF VEGETABLE ORIGIN:

	mg. per cent.	*mg. per oz.*
Cereals:		
Wheat	5·0	1·5
White flour	1·0	0·3
Rice (unmilled)	2·0	0·6
Rice (highly milled)	0·4	0·1
Rice (parboiled)	1·8	0·5
Maize	3·5	1·0
Millets	6·0	1·7
Pulses:		
Grams, Dhalls	8·0	2·3
Roots:		
Potatoes, Yams	1·0	0·3
Pumpkin, Gourds	1·0	0·3
Vegetable fruits:		
Drumsticks	5·0	1·5
Brinjal, Ladies' fingers, Plantain (green), French beans	1·0	0·3
Leaves:		
Cabbage, Lettuce	0·7	0·2
Amaranth, Centella, Lasia, Parsley, Spinach, etc.	5·0 to 20·0	1·5 to 6·0
Fruits:		
Fresh fruits	0·4	0·1
Dried fruits	4·0	1·1
Nuts:		
Coconut	0·4	0·1
Other nuts	1·5	0·4

Copper

This mineral plays at least two roles in the body, firstly, certain oxidases are cu-protein compounds; and secondly, copper is necessary for the healthy formation of blood and a deficiency of it in animals leads to a macrocytic hyperchromic anæmia. Copper is present in the red blood corpuscles, but does not form part of the hæmoglobin compound. Keilin and Mann [1] isolated from blood a blue crystalline cu-protein and named it *hæmocuprein*. A similar compound occurs in the blood serum and the organs of the body, that isolated from the liver has been named hepatocuprein.

The amount of copper in the blood is very small, ranging from 110γ to 140γ per 100 ml.

Much that is known concerning a deficiency of copper in the animal body has been learnt from the effects on cattle which have been kept on pastures where the copper of the herbage is only between 1–4 parts per million on a dry basis, they suffer from anorexia, anæmia, diarrhœa and emaciation. On such pastures newborn lambs develop "*swayback*," an ataxia due to changes in the spinal cord. These diseases can be prevented or cured by giving small doses of copper salts to the animals; or the pastures may be rendered safe by dressing them with copper salts. Lands where the grasses contain 6–8 p.p.m. on a dry basis are safe; there are pastures where the amount of copper in the dried fodder is as high as 35 p.p.m.

Milk is deficient in this mineral, and both iron and copper are needed to cure the anæmia of animals which have been fed on milk only. The hair of rats kept on a milk diet becomes grey, and this can be prevented or cured by the administration of copper.

Children may become anæmic when they are weaned to milk and refined cereal diets. It is customary among some tribes for the infants to remain at the mothers' breast for as long, maybe, as two years, and they tend to become anæmic. These anæmias due to excessive milk in the diet beyond the normal age of weaning are quickly cured by the administration of both iron and copper.

The daily requirements of copper are very small indeed, so that a deficiency of it is improbable except in milk-fed infants. Scoular [2]

[1] *Nature* (1939), 143, 333.

[2] *J. of Nut.*, 16, 437.

carried out balance experiments with three young boys and came to the conclusion that their requirements were between 0·053 and 0·085 mg. daily per kilogram of weight. There may be areas, however, where a more or less vegetarian population lives mainly on the produce of a copper deficient soil.

Table XIX gives in round figures the average amount of copper in various classes of foodstuffs in countries where there is no marked deficiency of this mineral in the soil.

TABLE XIX

	Copper in mg. per 100 gm.		
Cheese	0·02	Banana	0·20
Eggs	0·25	Brans	1·20
Fish	0·20	Cereals	0·35
Liver (beef)	4·40	Chestnuts	0·60
Liver (calves)	2·20	Cocoa	3·30
Meats	0·15	Coconut	0·70
Milk	0·02	Fruits	0·10
Poultry	0·30	Fruits (dried)	0·35
Oysters	3·00	Nuts	1·20
		Pulses	0·70
Vegetables: Fruits, Leaves, Roots	0·10		

Magnesium

This mineral enters into some enzyme systems and is needed for excretory purposes, and in very small amounts for bone formation. Magnesium has interactions with other minerals, and calcium may be partly replaced by it in the secretion of urine.

A deficiency of magnesium may be responsible for certain forms of tetany in calves and milk fever in cows.

It appears to be present in sufficient amounts in all usual human diets, but it has been suggested that some diets do not contain enough for the demands of pregnancy and lactation.

The adult daily requirements have been estimated as low as 0·2 gm. and as high as 0·6 gm.

Sulphur

Although small amounts of sulphur are taken into the body in the form of sulphates, much the greater amount of this element in

the tissues and excretions comes from the proteins of the food—mainly from the two amino-acids cystine and methionine. The metabolism of sulphur and nitrogen runs parallel under normal conditions. The sulphur from broken-down proteins is oxidized and excreted in the urine as sulphates.

When the protein supply is adequate in quantity and kind the sulphur requirements of the body will have been met.

Manganese

The necessity to animals of this element was first demonstrated by Orent and McCallum [1] in 1931. They showed that manganese-deficient rats became sterile with testicular degeneration, and females produced young which failed to survive. Manganese is also needed by animals for good growth and normal health.

A curious condition of chicks, called perosis, may be produced by manganese deficiency ; this is an osteodystrophy with enlargement of the tibial-metatarsal joint and twisting and bending of the bones, and the slipping of the gastrocnemius tendon from its condyles, which results in severe crippling. It is strange that a similar perotic malformation occurs in deficiencies of cholin and biotin. Manganese is also essential for plants, fungi and certain bacteria.

The element has been found to activate a number of enzymes such as the phosphatases of blood and bone, but other divalent ions, including iron, magnesium and cobalt, have a similar action, and may possibly be interchangeable with manganese in some enzyme systems.

Manganese has never been shown to be deficient under natural conditions in the diet of animals or man. The element is present in the human body to the extent of 0·3 mg. per 100 gm., and it is present in most diets in considerably greater amounts than this.

Trace Elements

A number of elements have been loosely grouped as *Trace Elements*, because they occur in the body in very minute amounts. Some of them are of physiological importance, others are not.

[1] *J. Biol. Chem.*, 92, 651.

FOOD TECHNOLOGICAL RESEARCH

More knowledge, however, is needed concerning most of them. They include iodine, cobalt, zinc, aluminium, fluorine, arsenic, silicon, boron and bromine.

Iodine. This mineral is essential for the formation of thyroxin, the hormone of the thyroid gland. There are about 15 mg. of iodine in the thyroid of a healthy adult, and about 10 mg. are distributed through the rest of the body.

Combined iodine is present in the rocks of the earth's crust, and the traces in the soils are derived from these stores ; the far larger amounts in sea water have been leached from the rocks and carried thence down the rivers through æons of time. Consequently the products of the sea are far richer in iodine than the products of the land. A deficiency of iodine occurs in some inland localities in the United States, Europe and other parts of the world, and is due to a shortage in the soils being reflected in the products of them and the drinking water. Goitre in adults and cretinism in children follows this deficiency. But not all goitres are due to iodine deficiency, some waters are goitrigenous even to persons receiving a sufficiency of iodine, and the reason of this is not known.

The prevention of goitres requires the frequent taking of an iodide. It may be added to table salt in the proportion of 1 in 50,000 or to the drinking water in much smaller amounts.

Von Fellenberg has estimated that the normal human adult requires about 0·014 mg. of iodine daily ; but Orr and Leitch place the requirements at the much higher figure of 0·045 mg.

The commercial salt most widely used in tropical and sub-tropical countries is obtained from sea water. This is prepared in desert parts, or where there are long dry seasons. Shallow parts of lagoons are isolated by bunds, or flat land surfaces are flooded with sea water, and evaporation under the heat of the sun causes the greater part of the salt in the water to be deposited in a few weeks. Sea salt contains other minerals besides sodium chloride, and is better for general use than many refined salts sold in the market. Some of the iodine is lost during the evaporation of sea water, but it is present in most samples in sufficient amount to be a valuable addition to the iodine obtainable from other foodstuffs.

Salt-water fish, seaweed and shell fish, including molluscs and crustaceans, are the richest sources of iodine.

Cobalt. The knowledge of the physiological need of cobalt has come from a cattle disease, characterized by emaciation and anæmia, and called by various names in different parts of the world—"Denmark disease" in Western Australia, "bush sickness" in New Zealand, "salt sick" in Florida, "pine" in Scotland and "nakuruitis" in Kenya.

Investigations extending over a number of years have shown that in all affected localities the disease is preventable and curable by the administration of minute doses of cobalt; also dressing the land with $\frac{1}{2}$ lb. of cobalt salts per acre will successfully banish the disease. The grasses of unhealthy pastures contain only 0·01–0·07 p.p.m. of cobalt on a dry basis, whereas the figures for healthy pastures are 0·07–0·30 p.p.m. Both cattle and sheep may be affected and the disease can be cured by the small doses of 0·3 mg. and 0·1 mg. daily, respectively.

Horses have been grazed on these unhealthy lands without showing signs of being affected, whether horses need cobalt in smaller quantities than cattle or do not need it at all has yet to be discovered.

Human requirements, if any, are unknown.

Zinc. In 1934, Todd, Elvehjem and Hart[1] showed that zinc was essential for the rat. When young rats are fed on diets deficient in zinc, the growth is retarded, dermatitis and alopecia appear, wasting sets in and death may take place from six weeks onwards. Some of the rats show vascularization of the cornea, similar to that believed to be due to riboflavin deficiency (*vide* p. 104). This element enters into enzyme systems as a Zn-protein compound.

Zinc occurs in the animal body in quantities comparable with those of iron; in the case of milk it is present in somewhat larger amounts, namely 0·25–0·35 mg. per 100 gm.

Aluminium. This mineral is probably not nutritionally essential. It has received much attention since aluminium vessels have come into general use for cooking. Neutral foods cooked in aluminium vessels absorb negligible amounts, but acid foods and those cooked

[1] *Am. J. of Physiol.*, 107, 146.

with baking-powder take up small quantities of the metal, but only a very small percentage of aluminium which reaches the alimentary tract is absorbed. It may be concluded that the use of aluminium cooking vessels is not a hazard to health.

Arsenic. This mineral may or may not be a physiologically essential element, the evidence is inconclusive. But there may be circumstances when it is needed for good health, for instance, in one experiment it was shown to prevent selenious intoxication, where the addition of 5 p.p.m. to the drinking water of rats on diets containing 15 p.p.m. of selenium in the form of wheat grown on seleniferous soil gave complete protection against damage to the liver.

Bromine. There is no evidence that bromine is needed nutritionally although it is present in all foodstuffs. Table salt may contain as much as 1 mg. of bromine per gm. of chlorine.

Boron. This is essential for plants ; and although it is present in trace amounts in the bodies of animals, in milk and eggs, it has never been proved to be essential for animals.

Silicon. This may be needed for the healthy formation of the skeleton and the enamel of teeth. An abundant supply is always taken in with the food.

Fluorine. This mineral occurs in the teeth and skeleton and may be needed in minute amounts for the health of these structures. Cox[1] and his associates in 1939 reported that fluorides inhibit dental caries ; and this has been confirmed in experiments with rats by Fin and Hodge.[2] Fluorine, however, has received more attention because of the changes it causes in the teeth and bones when present in drinking water in greater amount than one part per million. This is dealt with in Chapter XVIII.

Selenium and Molybdenum are important because they may be present in poisonous amounts in foodstuffs grown on certain soils (*vide* Chapter XVIII).

Acid-base Balance

The reaction of the body fluids varies within narrow limits. Acids are produced by the katabolic processes of the body, they are

[1] *J. Dent. Res.*, 18, 481. [2] *J. Nut.*, 22, 255.

mainly the weak carbonic acid and the strong sulphuric acid, the latter is produced by the oxidation of the sulphur of proteins. The tissues must be protected against these, and this is done by the balance affected by three buffer systems :

(1) The alkaline-acid carbonate pairs $NaHCO_3 : H_2CO_3$ where excessive carbonic acid is excreted by the lungs.

(2) The alkaline-acid phosphate pairs $K_2HPO_4 : KH_2PO_4$. Excess of one or other is excreted by the kidneys.

(3) The basic amino and acid carboxyl groups of the proteins. In this case ammonia derived from the amino-acids plays a part.

These systems are well adapted to correct small variations in the reaction of the tissues. There are two factors in ordinary human diets which affect these systems ; firstly, the relative amounts of the bases—sodium, potassium, calcium and magnesium, and the acids—phosphate, chloride and to a less extent sulphate—in the food ; and secondly, the amount of certain organic acids, such as citric, in fruits and vegetables, which are oxidized to alkaline carbonates in the body.

When the acids in a food predominate over the bases it is designated an *acidic-ash food*, or an *alkaline-ash food* when the bases predominate.

The acid- or base-forming capacity of a food is determined by titrating the ash against normal NaOH or HCL and recording the result in millilitres required for neutralizing 100 gm. of ash.

Tables XX and XXI give in approximate whole numbers the acidity or alkalinity of some acidic-ash and alkalinic-ash foods respectively.

TABLE XX

Acidic-ash Foods

Animal origin	*Degree of acidity*	*Vegetable origin*	*Degree of acidity*
Eggs	11	Bread	7
Fish	10–17	Maize	6
Meats	12–17	Oatmeal	13
Oysters	30	Peanuts	4
		Rice	8
		Wheat	10

TABLE XXI

Alkaline-ash Foods

	Degree of alkalinity		*Degree of alkalinity*
Milk	2	Lemon juice	4
Apples	4	Olives	47
Apricots	7	Onions	1
Bananas	6	Oranges	6
Beans (dried)	18–40	Peas (dried)	5
Beans	5	Pineapple	7
Cabbage	4	Potatoes	7
Carrots	10	Potatoes, sweet	7
Chestnuts	7	Pumpkins	2
Cucumber	8	Spinach	27
Dates	11	Tomatoes	6

Tables XX and XXI show that all foods of animal origin, except milk, have acidic ashes, and it might appear that carnivorous animals and hunting tribes would have difficulty in maintaining the normal alkalinity of their blood; but the adaptability of the body to "acid" or "alkaline" diets is considerable, provided there is a sufficiency of carbonates and phosphates in the diet, and carnivorous animals obtain an ample supply of these from bones.

The actual acidity of a food is no criterion of its reaction values, as already mentioned, the organic acids of fruits become alkalis in the body. The acidity of a fruit such as a sour orange is due to citric and other organic acids. Some fruits contain benzoic acid, and this is not changed to alkalies (*vide* p. 230).

CHAPTER IV

VITAMINS: HISTORY, ANIMAL EXPERIMENTS, ETC.

Certain substances, unrelated chemically, which are not proteins, carbohydrates, fats or minerals, and which are present in minute amounts in most foodstuffs and are necessary for growth and health, have been called *accessory food factors* or more commonly *vitamins*. Their functions are to take part in various metabolic processes of the body.

History

The discovery of the vitamins is typical of other scientific discoveries. It started with vague surmises and gropings in the dark until a few salient facts were well established and formed a needed foundation for work in laboratories.

The history may be considered to have started with the slow realization that the disease scurvy was due to a dietary error. Scurvy has always been associated with the use of stored or salted foodstuffs. Doubtless in ancient times it had been common in besieged towns, but it did not obtain mention in the literature until the time when ocean voyages far from land were first undertaken by Europeans. Vasco da Gama sailed round the Cape of Good Hope in 1498 and lost from scurvy 100 out of 160 men of his crew. Sir Richard Hawkins stated in 1593 that within his knowledge 10,000 seamen had died of scurvy. There are many other records of the toll this disease levied on the crews of ships in the early days of long voyages.

Perhaps the first mention of the cure of scurvy by the use of a fresh vegetable preparation was in reference to the second voyage of Jacques Cartier to Newfoundland in 1535, when scurvy broke out among his men, and 100 out of the crew of 103 became seriously ill. On the advice of Red Indians a decoction of the needles of the spruce tree was prepared and given to the men. It is related that the effect of the treatment was astonishing, the scurvy disappearing very rapidly.

Two names stand out in connection with the dietetic treatment of scurvy in the eighteenth century. The first was an Austrian army doctor named Kramer, who wrote that " 3 or 4 ounces of orange or lime juice will cure this dreadful disease without other help." The second was Captain Lind, a British naval surgeon, who published a " Treatise on Scurvy " in 1757. Lind in this book was more scientific than was usual among medical men in those days, for he not only reviewed all past work but gave an account of experiments he had carried out on sailors to show convincingly that the disease could be prevented or cured by the use of salads and summer fruits.

Much of the success of the celebrated explorer Captain James Cook was due to the attention he paid to the health of his crews. He relates in his " Voyage towards the South Pole and Round the World " how he obtained stores of sauerkraut, lemons and oranges, and made his men eat fresh food " both of animal and vegetable kind " whenever possible.

It had become apparent that certain articles of food would preserve the health of crews during long voyages, so regulations were passed in 1804 enforcing the daily use of rations of lemon juice in the British Navy. Several hundred patients suffering from scurvy had been admitted yearly to the Haslar Navy Hospital, but after the introduction of lemon juice the disease became a rarity.

The British Board of Trade adopted similar regulations in 1865. The issue of a ration of lime or lemon juice in British ships appeared an amusing custom to Americans, who considered rum a more suitable drink for sailors, and they nicknamed British seamen " limies," a word still used in many parts of America in reference to Britishers.

Beriberi is next in importance for the part it has played in the discovery of the vitamins. The disease is a neuritis which may lead to general paralysis ; when steam rice mills were introduced into many countries in the " Far East " the disease became prevalent (*vide* p. 208).

When the Japanese were building up a navy on European lines they were greatly troubled by outbreaks of beriberi among the crews of their ships.

Takaki, a naval surgeon, studied the comparative conditions on British and Japanese ships ; the disease did not occur in the former, and he came to the conclusion that the principal difference was in the diets. The training naval ship *Rinjio* returned to Japan in 1881 from a voyage round the world, and out of a total complement of 376 officers and men there had been 169 cases of beriberi with 25 deaths. In 1882 the naval authorities of Japan allowed Takaki, a comparatively young man, to ration the ship *Taukuba* more or less on British lines and sent it on exactly the same world voyage which had been completed by the *Rinjio.* Only 14 of the crew of the *Taukuba* acquired beriberi, and it is stated that these men had failed to eat the allowance of the foods new to them. Takaki had included meat in the rations and had replaced much of the rice by other cereals, mainly barley. Takaki's new diet was adopted throughout the Japanese Navy, and the result was that soon beriberi no longer occurred. Table XXII shows the number of cases before and after the work of Takaki.

TABLE XXII

Result of Changing the Rations in the Japanese Navy

	1878	1879	1884	1885	1886	1887	1888
Number of cases of beriberi	1,485	1,979	718	41	3	0	0
Percentage of all seamen	33	39	13	0·6	—	0	0

These results did not clarify the matter at the time. There were two reasons for this : firstly, Takaki believed that the outbreaks of beriberi were due to protein deficiency, and secondly, there was a widespread belief that beriberi was due to some infection. The vagaries of infection may be used to explain any figures.

The next step was taken by Eijkman, who had medical charge of a prison in the Dutch East Indies. Beriberi occurred among the prisoners and he noticed that some of the fowls kept in the prison yard and living almost exclusively on waste rice from the prisoners' diets showed signs of polyneuritis. This led him to carry out feeding experiments, and he soon discovered that when the diets of fowls were confined to milled rice they developed polyneuritis. Eijkman's publications started work in other countries, and it was shown that the outer layers (the pericarp) of the rice grain which

are removed by milling, contain something which will prevent or cure beriberi in human beings.

Rickets is another disease which has played a part in the discovery of the accessory food factors. Towards the end of last century there was a growing opinion that rickets was due to faulty diets, and Cheadle stated in " Artificial Feeding of Infants," published in 1889 : " rickets is produced as certainly by a rachitic diet as scurvy is by a scorbutic diet." It was recognized a few years later that cod-liver oil had curative properties in the treatment of rickets. But, as might be expected from the chemical analysis of bones, most attention was directed to the calcium and phosphates in the food, and it was not realized until more recent times that the utilization of these for healthy growth depended upon another factor.

Animal Experiments

Whilst the clinical observers were slowly advancing in knowledge, many animal experiments were being done by physiologists. In 1881 Lunin,[1] a pupil of Professor Bunge of Basle, showed that mice could not survive on diets of purified fats, carbohydrates, proteins, salts and water, and he concluded that, apart from these known constituents, natural foods contain " unknown substances essential for life." Stepp attacked the problem in another way : he extracted bread and milk thoroughly with alcohol and ether, and fed the residue to mice, but they wasted and died ; when, however, other mice were fed on the residue to which the extracted matter had been returned, they thrived. Stepp therefore argued with reason that bread and milk contained unknown alcohol or ether soluble substances essential for life.

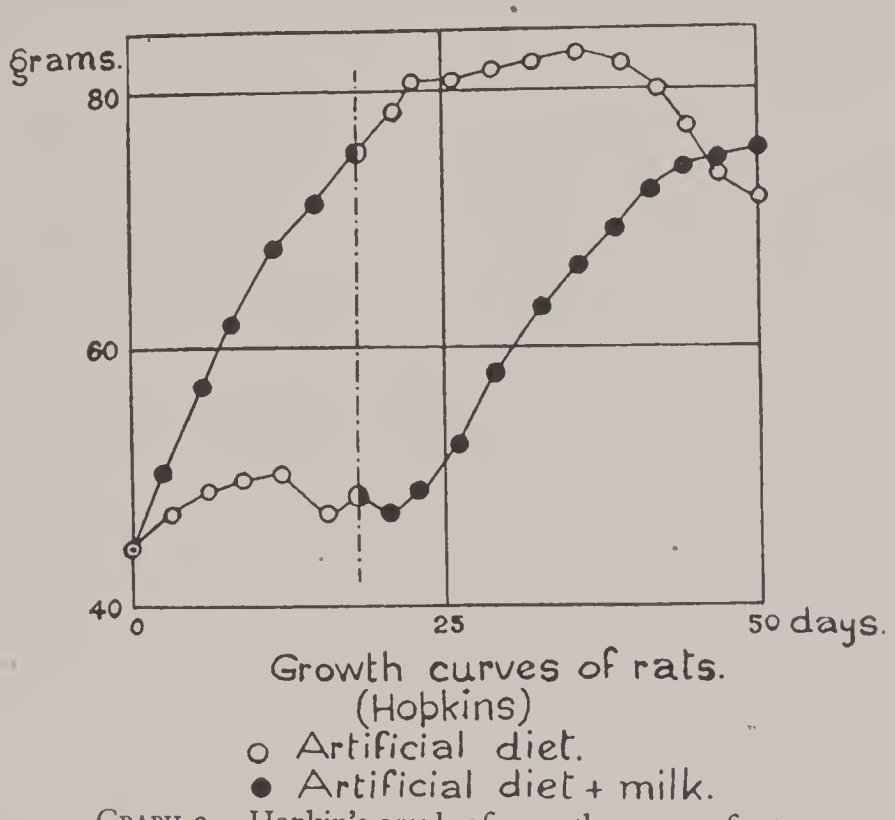
The Dutch physiologist Pekelharing, experimenting with mice, likewise found that they died on a mixture of all the purified known constituents of diets, but he discovered also that the addition of very small quantities of milk or whey to the diets would enable the mice to survive, and he concluded in a publication in 1905,[2] " that there is still an unknown substance in milk which even in very small quantities is of paramount importance to nutrition."

[1] *Hoppe-Seyl. Z.*, 5, 31.

[2] *Ned. Tydschr. Geneesk.*, 70, III.

Eijkman had discovered that the filtered extract of rice millings would prevent or cure polyneuritis in fowls. One of his colleagues named Grijns [1] suggested in 1901 that beriberi followed the use of diets which "lacked certain substances of importance in the metabolism of the central nervous system."

Beriberi was common at one time among the crews of Norwegian timber ships, and two scientists named Holst and Frolich [2] working in Oslo in 1907 carried out experiments on guinea-pigs



GRAPH 2. Hopkin's graph of growth curves of rats

in an attempt to produce that disease; they failed, but the guinea-pigs fell sick of a disease which had all the characteristics of scurvy in man. Thus having discovered, more or less accidentally, a method of producing scurvy in guinea-pigs, they abandoned the question of beriberi and investigated the curative and preventive effects of many foodstuffs on scurvy. Also they did important work determining the effects of drying and storage on the anti-scorbutic factor in foods.

There were a number of criticisms of these early researches,

[1] *Geneestk. Tydschr. Ned. Ind.*, 41, 3.

[2] *J. Hyg. Camb.*, 7, 634.

such as that the diets of purified substances given to the animals were too monotonous and became distasteful, so that the animals allowed themselves to starve, or that the chemicals used for the purification had deleterious effects on the foods and led to poisoning or rendered the foods unsuitable for nutrition.

Sir Gowland Hopkins [1] in 1912 recorded a series of well-planned feeding experiments on rats. Graph 2 summarizes his results ; the left-hand curve shows that young rats on a diet of purified proteins, carbohydrates, fats and salts together with a little milk (2 ml.) grew well, but when after the third week the diet was given without the milk, growth gradually ceased and was followed by wasting. The right-hand curve shows that other young rats were on the purified diets without the milk for three weeks and did not grow, but when milk (2 ml.) was added to the diet it was soon followed by good growth. He found that not only milk but also extracts of yeast promoted growth when given in astonishingly small amounts.

These experiments have become famous, although they were little more than a repetition of the experiments of Lunin, Stepp and Pekelharing, but the time was ripe for general acceptance of the existence of accessory food factors, and Hopkins had a well-earned great reputation as a biochemist.

The Origin of the Word " Vitamin "

The time was now ripe for the creation of a word for the accessory food factors so as to systematize the knowledge which had been and was being acquired. This was done in 1912 by Casimir Funk, a Polish biochemist. He was attempting to isolate the substance which prevented beriberi, and believed that he had isolated it in a pure form, and that it belonged to a group of substances called *amines*. He suggested that certain amines were present in foods and guarded the body against beriberi, scurvy, rickets and pellagra, and were necessary for vital processes, therefore he called them " vitamines." It was soon discovered that all accessory food factors are not amines, and the final " e " has been dropped. (But it is difficult to understand why this should make the word more suitable.)

[1] *J. Physiol.*, 44, 425.

Thus the gradual emergence of the knowledge of the existence of vitamins has come along two lines—clinical observation and animal experiments.

Table XXIII gives a short summary of the steps of progress up to the year 1912.

Since 1912 much clinical work in different parts of the world

TABLE XXIII

Summary of the Gradual Emergence of the Idea of the Existence of Vitamins

Clinical Observations		*Animal Experiments*	
DATES AND OBSERVERS		DATES AND OBSERVERS	
	Scurvy	1881 Lunin	Mice cannot survive on diets of purified proteins, fats, carbohydrates and salts.
1720 Kramer 1757 Lind	Due to lack of fresh foods, can be cured or prevented by fresh fruits and vegetables.	1897 Eijkman	Polyneuritis in fowls produced by feeding on highly milled rice, can be cured or prevented by rice millings.
	Beriberi		
1882 Takaki	Prevented by meat, wheat, barley and milk.		
1897 Eijkman	Due to highly milled rice, prevented by unmilled rice or rice millings.	1901 Grijns	" Polished " rice lacked an essential food substance.
		1905 Pekelharing	Milk added in very small quantities to purified diets enable mice to thrive.
	Rickets		
1889 Cheadle	Due to faulty diets.		
		1907 Holst and Frolich	First produced scurvy in guinea-pigs and tested curative value of foods.
		1909 Stepp	Bread and milk after extraction with alcohol and ether is an inadequate diet, replacement of the extract makes it adequate.
		1912 Hopkins	Experiments to show the presence in milk and yeast of accessory food factors.

1912 Casimir Funk named the accessory food factors " vitamines " (spelling later altered to " vitamins ").

and vast numbers of animal experiments in laboratories have produced a massive newer knowledge of nutrition.

Names of the Vitamins

The vitamins have been named alphabetically, vitamin A, B, C, D, etc. But some of them have been found in the light of further work to consist of more than one substance ; thus vitamin B has been divided into B_1, B_2, B_3, B_4, etc. This method of naming a vitamin is justified so long as it is hypothetical from the results of its deficiency in a diet ; but, after it has been isolated in pure form and some of its properties and chemical structure determined, it should receive an appropriate name. This is slowly taking place and names are being substituted for letters—thus thiamine or aneurin for B_1, ascorbic acid for C, nicotinic acid for PP and riboflavin for B_2 (American G). But the process of conversion is bound to lead to some confusion and to be slow because of past associations.

The Number of Vitamins

The more important vitamins have probably been discovered, but undoubtedly there are a few, sometimes called minor vitamins, which remain to be discovered. The following is a list of the well-established vitamins :

Vitamin A	.	(The provitamin is Carotene).
Vitamin B_1	.	Thiamine, Aneurin.
Vitamin B_2	.	Vitamin G of American literature—Riboflavin.
Vitamin B_6	.	Pyridoxine, Adermin.
Vitamin C	.	Ascorbic acid, Cevitamic acid.
Vitamin D	.	(Calciferol, Viosterol).
Vitamin E	.	Tocopherols.
Vitamin F	.	(Essential unsaturated fatty acids).
Vitamin G	.	(Vitamin B_2).
Vitamin H	.	Biotin, Co-enzyme R.
Vitamin K	.	(Naphtoquinones).
Vitamin P	.	" Citrin " (hesperidine).
Vitamin PP	.	Nicotinic acid.
(Filtrate Factor)		Pantothenic acid.

Some of the letters have been confusingly used for more than one vitamin, for instance, Sherman divided the Bs into vitamins

F and G, and F was later used for certain unsaturated fatty acids ; and the name vitamin H has been used for two different factors.

Factors apparently necessary for pigeons or rats have been called vitamins B_3, B_4 and B_5. Cholin may well be placed among the vitamins (*vide* p. 148).

Folic Acid, inositol and para-aminobenzoic acid (vitamin B_x) are needed by mice and rats (*vide* pp. 120 and 147).

Vitamin L is a name given to a hypothetical vitamin supposed to be needed for lactation.

Nature of the Vitamins

The vitamins are definite chemical substances and many of them have been prepared in pure crystalline form and their chemical structures determined. The physiological activities of the vitamins are being gradually discovered, some, if not all, of them enter into various enzyme systems. These systems are made up of protein molecules to which are attached one or more groups of non-protein substances, these groups are called prosthetic, and neither the protein molecules nor the prosthetic group can act alone. A vitamin enters an enzyme system always as a prosthetic group. Other substances such as metallic compounds can also form prosthetic groups.

Measurement of Quantities of a Vitamin

Whilst the vitamins were known only from the results of deficiencies of them in diets, they could not be weighed ; and various units of measurement were founded upon the cure or prevention of one or all the signs of disease known to follow a lack of each particular vitamin in a diet of some laboratory animal susceptible to the deficiency.

Thus one unit of vitamin C was defined as that amount which, when fed as a daily allowance, just suffices to afford complete protection from scurvy to a standard guinea-pig under certain experimental condition. A defined unit of vitamin B_2 (G of American literature) was that amount which when fed daily to a standard test animal under defined experimental conditions results in an average gain of 3 gm. per week during the test period.

The next step was taken by an international committee which defined the unit of some particular vitamin as the potency of a definite quantity of some more or less pure preparation, and such a unit was called an *International Unit*, or I.U. for short. Thus the I.U. of vitamin A was defined as the vitamin A value of 1 gamma (γ) (0·001 mg.) of a certain carotene preparation. It was soon found, however, that this preparation was a mixture of α and β carotenes, and the I.U. was redefined as 0·6 gamma of pure β-carotene.

This is all very confusing, and the needs are that each vitamin shall have a definite name, and that quantities of it shall be in terms of milligrams or micrograms. At present the period is one of transition.

Vitamin Deficiencies

These may arise in two general ways.

(1) *Deficiencies in Diets.* There are a number of diseases due to this, and well-known examples are scurvy, rickets, beriberi and pellagra ; but the particular vitamins concerned must be markedly deficient in the diets for any of these diseases to occur in a frank form, also in most cases the diets have been deficient in more than one vitamin or other factor such as a mineral. The labouring classes of many tropical lands subsist on poor and monotonous diets which are often far from satisfactory in more than one respect, and various signs and symptoms of vitamin deficiencies of a less urgent nature than occur in the above-mentioned diseases are rife among them, and especially among their children.

(2) *Conditioned Deficiencies.* These may be brought about in several ways :

(*a*) Some vitamins require other substances for absorption from the intestine, for instance, vitamin K requires bile salts and a conditioned deficiency follows obstructions of the bile passages. Again, the fat soluble vitamins A and D need adequate fat in the diet or they will not be well absorbed.

(*b*) Deficiencies may follow diseases of the bowel, which impair absorption. Neuritis following such diseases as dysentery or typhoid, and many of the signs and symptoms of sprue are probably due to faulty absorption of vitamins.

(*c*) Vitamins may be destroyed or rendered unabsorbable[1] by some substances in the food. No definite example of this leading to disease have been demonstrated in respect of human diets, but two interesting examples have come to light in respect of animal diets : one is Chastek's paralysis on fox farms due to raw fish destroying vitamin B_1 in the diets of the foxes, the other is " egg white injury " in which biotin combines with avidin of egg white (*vide* p. 117).

(*d*) Poisons or the toxins of disease may inhibit metabolic utilization of vitamins. Perhaps alcoholic neuritis is of this nature, because in many cases it may be successfully treated by the administration of vitamin B_1. Dr. Alfred Clark[1] is a protagonist of the view that poisons naturally occurring in foodstuffs (for instance HCN in manioc) inhibit the action of vitamins in the body.[2]

The Determination of the Vitamin Values of Foodstuffs

A knowledge of the quantities of vitamins in various foodstuffs is needed by all concerned with nutrition ; and the clinician needs to know for diagnostic purposes the amounts in the blood and urine as an indication of a sufficiency or otherwise of the amounts absorbed from the alimentary tract.

The original methods of estimation were by animal experiments known as *biological assays*. But some of the vitamins can now be determined by chemical analyses ; the methods, however, are in most cases complicated and involved, and can be carried out only by experienced biochemists in well-equipped laboratories. This greatly limits the value of chemical methods, especially for clinicians. Perhaps the time is not far off when the quantitative determinations of all vitamins will be done by chemical methods sufficiently practicable for clinical laboratories.

Biological Assays[3] are complicated procedures which require much

[1] *J. Trop. Med. and Hyg.*, 1936, 39, 271.

[2] Liquid petrolatum dissolves fat soluable vitamins and prevents their absorption. Magnesium trisilicate or aluminium hydroxide given as drugs may absorb other vitamins.

[3] See " Biological Standardisation of the Vitamins," K. Coward. Baillière, Tindall and Cox.

experience. An example for the determination of vitamin A in a foodstuff may be briefly described as follows :

Young animals are used so that their rates of growth may be watched. Foodstuffs freed from vitamins are mixed to form a basal diet such as the following :—

Purified caseinogen to supply protein.
Dextrinised rice starch to supply carbohydrates.
Olive oil to supply fats.
Agar to supply bulk.
Salt mixture.

It is necessary to add the other vitamins ; brewer's yeast is added to supply the vitamins of the B complex ; irradiated ergosterol supplies vitamin D ; vitamin C is not needed by rats, although it may be supplied in the form of lemon juice. Thus the diet is complete except that vitamin A is absent. Many young rats required for the test are fed on this diet, and they are weighed at short intervals. At first they show no changes in health, but in two or three weeks they cease to grow, and if the diet is continued they will develop various signs of vitamin A deficiency, but it is not necessary to wait for these signs, and as soon as their growth becomes stationary they are divided into a number of batches. The rats of one batch are each given an amount of vitamin A (usually in the form of a standard sample of cod-liver oil) which is just sufficient to produce normal growth ; the rats of the other batches are given different quantities of the foodstuff being tested, thus the rats of one batch may each receive 1 gm. of the foodstuff and the rats of other batches 2 gm., 4 gm. and so on, respectively. It may be accepted that the amount of the foodstuff, which is just sufficient to enable the average rat to grow at the same rate as the average rat of the control batch, will have the same vitamin A value as the amount of cod-liver oil given to each rat of the control group.

Biological Experiments. The greater part of the vast knowledge of the vitamins built up in recent years has been derived from biological experiments. Many forms of life have been used, because one form may be more suitable than another for showing the presence in various amounts, or the absence of a particular vitamin : for instance, puppies or rats are most suitable for experiments with

vitamin D, because they soon become rachitic without it ; whereas birds are often preferred for work with vitamin B_1 because, when it is absent from their diets, they develop polyneuritis far more quickly than mammals ; chickens are used when dealing with vitamin K because they are very susceptible to a lack of it. Insects, plants and bacteria have been used. The little flour beetle, *Tribolium confusum*, has been known for past ages as a pest of cereal meals, but it does not greatly multiply in refined flours, this is because its multiplication depends more or less on vitamins which are present only in traces in refined flours, this has been applied to test for and estimate the amounts of vitamins in cereal flours.

Plants need vitamin B_1 and small pieces from tomato roots placed in solutions of salts needed for plant growth will grow only if traces of vitamin B_1 are present, and the degree of growth varies with the amount of the minute quantities of the vitamin.

Certain bacteria require traces of certain vitamins for their multiplication, and they have found a place in some laboratories for the estimation of trace amount of some vitamins.

Many of the results of biological experiments are applicable, with reasonable reservations, to human nutrition, but not all of them, because the needs of men and animals are not exactly similar, and the circumstances of animal experiments with the use of chemically purified diets and the confinement in cages without exercise are never paralleled in human life.

Many animals do not require vitamins ready formed in their food because they are either able to synthesize them or to absorb those produced by bacteria in the food as it passes along the alimentary tract. The latter is called *refection* ; and apparently all animals under certain circumstances, and in the case of some vitamins, may obtain their needed supplies from the bacteria within their guts, even though for any particular vitamin this is not the normal source of supply.

Refection accounts for many vagaries in animal experiments, such as when the workers in one laboratory obtain results from similarly planned experiments at variance with the results from other laboratories. It may also account for certain apparent inconsistencies in outbreaks of human deficiency diseases, such as where a number

of persons partake of the same diet and some become diseased and others escape.

Men, monkeys and guinea-pigs are the only animals known to need vitamin C in their diets, others such as rats and dogs are able to synthesize it or obtain it by refection.

Ruminants do not require certain vitamins in their food. Many years ago Sir Arnold Theiler [1] carried out several feeding experiments and reported in 1915—" it may be that cattle are capable of synthesizing their own vitamins in virtue of the extensive bacterial flora of their intestinal tract." Since that time McElroy and Ross [2] have shown that when cattle or sheep are fed foodstuffs deficient in vitamins of the B complex (riboflavin, pyridoxine, thiamine and nicotinic acid) and vitamin K, and the animals are slaughtered a few hours later, and the contents of the rumen and reticulum assayed, the amounts of the vitamins have greatly increased, presumably from bacterial action.

Commercial and Domestic Actions which Affect the Content of Vitamins in Foodstuffs

The vitamin values in foodstuffs may be lessened or destroyed in four ways :

(1) Mechanical removal.
(2) Chemical action (usually oxidation).
(3) Heat and oxidation.
(4) Leached out by water.

The destructive processes will be mentioned only briefly here as they are described in more detail under particular vitamins and foodstuffs.

(1) *Mechanical Removal.* Vitamins are stored in seeds, such as wheat and rice, for the future use of the young plant ; and the site of greatest storage is in the outer coats, which are removed as brans and various meals during the process of milling, hence white flour and milled white rice have lost much of the original vitamin content of the whole seed. Also some roots and fruits carry a greater quantity of vitamin in that part which is removed as peel.

[1] Union of South Africa Dept. Agri., *Dir. Vet. Res. Reports*, 3, 4.
[2] *J. of Nut.*, 20, 525.

(2) *Chemical Action.* Most vitamins may be slowly destroyed by oxidation, and although this takes place in most foodstuffs during prolonged storage or exposure to air, yet for many vitamins the amounts destroyed are so small as to be unimportant. The marked exception is the anti-scorbutic vitamin C. A few incidents in the history of scurvy among sailors, who must live on stored food, have been mentioned previously. This vitamin is so easily oxidized that when fruits or vegetables are cut up finely (shredded), which exposes large areas of the interior to the air, half or even more of the content of vitamin C may be lost in a few minutes. The oxidation of vitamin C even takes place in the interior of foodstuffs, for instance the amount in potatoes at the end of the winter may not be more than half the amount present when they were gathered from the soil.

It may be accepted as a general principle that as fruits and vegetables become stale some of the vitamin values of them are diminished.

Vitamins are far more easily destroyed by alkalies than acids ; and an example of the deleterious effects of chemical action is the use of the alkali sodium carbonate by manufacturers to preserve the colour of tinned vegetables, such as peas, and by cooks for various purposes.

(3) *Heat and Oxidation..* The destruction of vitamins by heat in almost all cases is due to the action of heat in increasing oxidation, therefore the two must be considered together.

At one time foods prepared by heat, such as tinned (canned) fruits and vegetables, contained little or no vitamin C, and other vitamins in them were also reduced, but to a smaller extent. Acidity, as in the case of tomato juice, prevented some of this destruction. At the present time many manufacturers have contrived methods to minimize this destruction in most preserves, even in jams, or they add vitamins to their various preparations.

Cooking may materially reduce the vitamins in foods and re-cooked foods are never satisfactory.

The use of superheated steam, passed through coils or jackets around cauldrons, for cooking large quantities of food has been introduced into the kitchens of many institutions such as hospitals

and prisons, and unless it is used with care the excessive heat may cause a serious destruction of the vitamins in the food.

Dehydration[1] of potatoes and other vegetables has been practised in recent years to preserve them and lessen the space needed for transport and storage. Unfortunately the amounts of the vitamins are reduced during the process; further losses occur when these products are stored, especially in the heat of the tropics; more loss may take place during cooking. All the vitamin C and about 30 per cent. of the vitamin B_1 have been destroyed in dehydrated potatoes mainly due to oxidation. Similar losses take place when eggs are dried to a powder.

There are, however, indications that improved methods of dehydration may prevent some of these losses.

(4) *Leached out by Water.* This occurs only in the case of water soluble vitamins, such as vitamins B_1, C, etc. When foodstuffs, such as rice, are given prolonged washing, a considerable amount of vitamin B_1 is dissolved into the water (*vide* p. 210). The same applies to leaving peeled roots in water for a long time before cooking. Boiling may leach out much of the soluble vitamins, and, wherever possible, such as in the case of rice and other grains, the quantity of water used should not be more than is taken up by the mass of the grains during the cooking, so that when the mass is removed from the pot no water remains. With meat and vegetables all cooking water should be reserved for broths and soups.

[1] *Amer. J. Pub. Health* (1943), 33, 799.

CHAPTER V

VITAMINS (*contd.*): VITAMIN A, VITAMIN B COMPLEX

VITAMIN A

"Carotinol"

The existence of this vitamin was first discovered independantly by McCollum and Davis,[1] and Osbourne and Mendel [2] in America in 1913. These investigators found that when young animals were fed on diets adequate in all respects except that lard was the only fat supplied they ceased to grow and became ill; but when the lard was replaced by butter they grew normally and thrived. Further work showed that egg yolk and cod-liver oil had the same effect as butter. In 1915 McCollum and Davis [3] showed that there were at least two accessory food factors necessary for normal growth and thus settled a long-standing controversy as to whether there was one vitamin only, or more than one. They called the one "fat soluble A" as found in butter and egg yolk and the other "water soluble B" as found in wheat but not in highly milled rice. As will be recorded in the pages which follow there are at least three "fat soluble vitamins" and many more than this which are water soluble.

Chemistry of Vitamin A

It was not until about fifteen years (1930) after the discovery of vitamin A that it was definitely established that foodstuffs of vegetable origin, such as carrots and green leaves, had the same nutritional effect as butter. The reason of this was explained by Moore [4] who showed that the yellow pigment of plants, called carotene, was converted into vitamin A in the animal body.

There are three carotenes (α, β and γ) and an allied substance cryptoxanthin which can act as precursors of vitamin A. The most effective of these is β-carotene because one molecule of it together with two molecules of water can be formed into two

[1] *J. Biol. Chem.*, 15, 167.
[2] *Ibid.*, 15, 311; *ibid.*, 16, 423.
[3] *Ibid.*, 23, 181
[4] *Biochem. J.*, 24, 696.

molecules of vitamin A whereas the other three can form only one molecule of the vitamin.

The researches of Karrer [1] and his associates have shown that the structural formulæ of β-carotene and vitamin A are as given on p. 75.

The conversion of carotene to vitamin A takes place in the liver presumably by means of an enzyme which has been called carotenase, as a preliminary to the demonstration of its existence. There is evidence that in some diseases such as diabetes the power of the liver to convert carotene to vitamin A is lessened. And some persons, who are apparently otherwise healthy, show a yellowness of the skin from carotemia, because of lack of power to convert the carotene to vitamin A ; but in some cases the condition may have followed too high a consumption of carrots or green leaves.

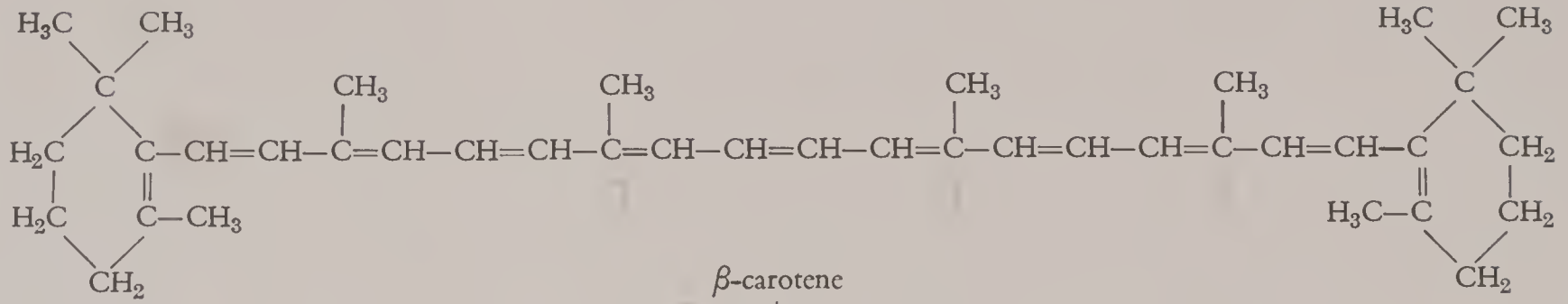
Carotenes are closely associated with the chlorophyl of green leaves. The carotenes are yellow in colour, but not all the colour of fruits and vegetables with yellow flesh are due to them, there are several other pigments such as zeaxanthin and flavoxanthin which are biologically inactive in the sense of being convertible to vitamin A.

Isolation and Synthesis. In the case of most vitamins the preparation in pure form from natural sources has preceded the synthesis, but there have been many difficulties in the case of vitamin A, which was first isolated in crystalline form by Holmes and Corbet [2] in 1936, whereas it had been synthesized a few months earlier by several teams of investigators.

Properties. Vitamin A is almost colourless in contrast to its yellow precursors. Baxter and Robeson [3] in 1940 isolated vitamin A as pale yellow prismatic crystals melting at 64° C. The carotenes are hydrocarbons (β-carotene is $C_{40}H_{56}$), whereas because of the position of the OH group, vitamin A is classified as an alcohol ($C_{20}H_{29}OH$). It is unsaponifiable, and the manufacture of concentrated preparations from fish-liver oil is based on this, because most of the oil can be removed in the form of soaps, leaving a small unsaponifiable fraction containing the vitamin A.

Spectrographic Analysis shows that vitamin A exists in two forms ; vitamin A_2 occurs in fish liver but not in mammalian livers.

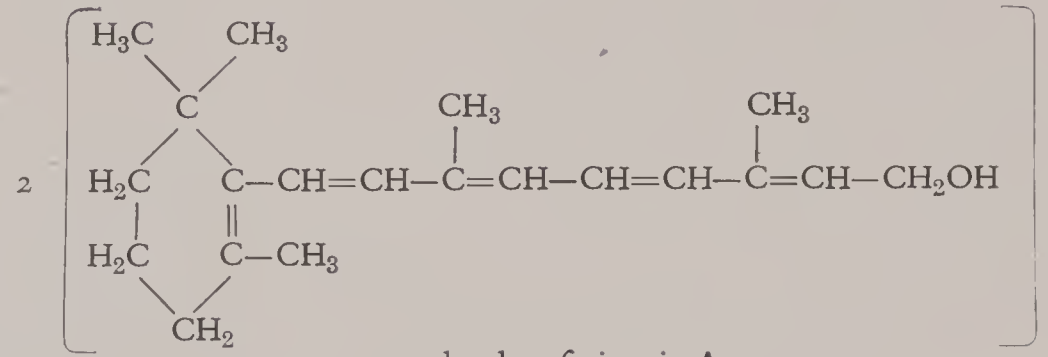
[1] *Helv. Chim. Acta*, 13, 1084. [2] *J. Am. Chem. Soc.*, 59, 2042.
[3] *Science*, 84, 294.



β-carotene

+

$2H_2O$



2 molecules of vitamin A

Action. The part played by vitamin A in the metabolic processes of the body has not been clearly defined. It appears to be stored in the liver either uncombined with other molecules or as esters, it is probable that in the latter form it acts as a posthetic group of a catalyst in an "oxidation reduction" system. The visual purple of the eye is a conjugated protein and vitamin A, or a derivative of it, is a prosthetic group in it.

Absorption of Vitamin A. There are several points of importance concerning the absorption of vitamin A and carotene from the intestinal tract :

(1) Vitamin A is more quickly absorbed than carotene and most of it has been absorbed in 3–5 hours after administration, whereas a similar amount of carotene requires 7–8 hours.

(2) Carotene is badly utilized on a low fat diet because fats are necessary of its absorption. This is a matter of great importance in respect of many tropical diets, which are more or less vegetarian and contain little fat.

(2) Hydrocarbon oils, such as paraffin, inhibit the absorption of carotene, and therefore under certain circumstances may be contraindicated as aperients.

(4) Bile salts are necessary for the absorption of both carotene and vitamin A, the latter is probably absorbed as a bile salt ester and may be stored as such in the liver.

(5) Absorption is low in fevers, enteric diseases, sprue and tuberculosis.

(6) Carotene is badly absorbed and utilized by infants at the time of weaning ; and for good growth and health young children require some ready formed vitamin A.

Storage of Vitamin A in the Body

Ninety per cent. or more of the vitamin A in the body is stored in the liver and the amount in any individual varies at different times, the liver of a person on a reasonably good diet, not unduly rich in vitamin A or carotene, will contain 200–400 I.U. per gm., which is sufficient to supply an adult on a diet deficient in vitamin A for several months. Some animals, such as rats, can store large

quantities of vitamin A in their livers whereas other animals, such as rabbits, cannot. Some species of fish continue to store vitamin A in the liver throughout their lives, and an aged halibut may possess a liver containing as much as 1 per cent. of its weight in this vitamin. The origin of the vitamin in the livers of fish is not known, it may be from minute amounts of carotene formed by the plankton of rivers or sea devoured by copepods which in turn are eaten by the fish ; but copepods contain very little carotene and vitamin A, and possible other pigments in these crustaceans may be metabolized to vitamin A in the livers of fish.

The storage of vitamin A in the human body is important, because there are many tropical races whose foodstuffs vary with the seasons of the year. After the onset of rains a supply of green leaves and other vegetables will allow vitamin A to be accumulated in the liver against the time, after the yearly drought sets in, when the foodstuffs may be deficient in this vitamin.

The Effects of Vitamin A Deficiency in Animals

Although the pathological changes taking place in animals on diets deficient in vitamin A had been studied for many years, it was not until 1925 that they were comprehensively summed up. This was done by Wolback and Howe.[1] They showed that the changes—almost specific—are a *keratinising metaplasia*. This may take place in any epithelium throughout the body, although this structure in some organs is far more susceptible than in others. The changes start as a degeneration of the epithelium concerned, followed by reparative proliferation of the basal cells, and the newly formed cells are differentiated into stratified epithelium comparable with that of the healthy epidermis. When the epithelium is normally stratified or transitional the atrophy and metaplasia due to the deficiency lead to marked degenerative changes. Many of the gross changes are due to accumulation of the keratinized epithelial cells in glands or ducts ; thus the process in the lungs may lead to the plugging of the bronchi and the formation of bronchiectatic cavities ; and similarly plugging of the sebaceous glands produces in man a typical follicular keratosis called phrynoderma.

[1] *J. Exper. Med.* (1925), 42, 753.

Young rats on a vitamin A deficient diet soon cease to grow unless they have large stores in the liver from a previous diet rich in the vitamin.

Eyes. Holm [1] (1925) showed that rats in an early stage of vitamin A deficiency were unable to jump off a table in a dim light after they had been exposed to a bright light; in other words, they had developed *night blindness* (hemeralopia) as the earliest sign of the deficiency. Fredicia and Holm [2] had already shown that vitamin A deficient rats had a subnormal rate of regeneration of visual purple. The rods of the retina are normally sensitive to dim light because they contain visual purple (also called rhodopsin). Wald [3] and others have brought forward evidence that rhodopsin is a conjugated protein with vitamin A or a derivative of it, as a prosthetic group, and when light falls on the rods the rhodopsin is converted into an orange yellow pigment called visual yellow or retinene, and this gives rise to the nerve impulse. In strong light rhodopsin is rapidly reduced and apparently can be resynthesized in two ways: (*a*) from retinene; (*b*) or when the retinene is reduced from protein and vitamin A circulating in the blood stream. In the case of vitamin A deficiency this resynthesis is delayed and the result is *night blindness.*

Xerophthalmia is a later sign than night blindness, but it does not appear in all vitamin A deficient rats. The first sign is swelling of the eyelids followed by inflammation of the conjunctiva; later there are hæmorrhagic and purulent discharges; the cornea becomes ulcerated and ultimately there is blindness. The lachrymal glands are affected early, and Findlay [4] has shown that the tears of vitamin A deficient rabbits are deficient in lysozyme. The changes in xerophthalmia are at first due to the degeneration of the epithelium, but later bacteria play the greater part, being unchecked by healthy epithelium and normal secretion of tears.

Teeth. Metaplasia and atrophy of the enamel-forming organ and the dentine of rats on vitamin A deficient diets have a profound effect upon the proper formation of the teeth.

Nervous System. Pigs and other animals on a vitamin A deficient

[1] *Amer. J. Phys.*, 73, 79.
[2] *Ibid.*, 73, 63.
[3] *Ibid.*, 116, 157.
[4] *Brit. J. Exp. Path.*, 6, 16.

diet acquire spasms of the limbs and inco-ordination with a staggering gait. On death, scattered myelin degeneration is found in the cord. Mellanby [1] has shown that carotene or vitamin A can protect animals from the action of neurotoxins such as ergot or the poison of the lathyrus pea (lathryism).

Mellanby has shown that vitamin A deficiency in young puppies leads to disordered growth of the bones, and the finer structures of these become coarse, and there may be local overgrowth in parts of the skull. Thus overgrowth in the bony canals through which the nerves pass may cause pressure on them and lead to deafness, blindness, loss of power of smell and various other sensory disorders. It appears that vitamin A restrains and co-ordinates the growth of bone so that it is in harmony with the growth of other structures. The close association of vitamin A with the calcium regulating vitamin D (q.v.) in egg yolk, milk and liver fats may have other significance than the fact that they are both fat soluble.

Infection. McCollum [2] as early as 1917 noted high rate of respiratory infection in rats on diets deficient in vitamin A. Green and Mellanby [3] studied on a large scale infections of rats on vitamin A deficient diets. They found :

38	per cent.	had	septic xerophthalmia.
72	,,	,,	an abscess at the base of the tongue.
44	,,	,,	infections of the genito-urinary tract ; some had calculi of the kidney or bladder.
20	,,	,,	middle ear or sinus sepsis.
9	,,	,,	infections of the lungs.

They suggested the name " anti-infective " vitamin, but this is not acceptable because other deficiencies also increase the susceptibility of animals to infections.

Among other conditions which have been found in experiments with rats is an abnormal frequency of gastric ulceration.

The Effects of Vitamin A Deficiency in Man

The earliest and most frequent sign is *night blindness.* This condition has received much attention in recent years, especially in

[1] " Nutrition and Disease " (Oliver and Boyd).
[2] *J. Biol. Chem.*, 29, 241.
[3] *Brit. Med. J.*, 1928, 691.

respect of those who drive vehicles or pilot aeroplanes at night. Many attempts have been made to establish a satisfactory diagnostic method for early or sub-clinical cases by photometric methods. Several types of photometric instruments have been used, but the general procedure is much the same with each of them. The subject enters a dark room, where he is exposed to a bright light for a definite time to bleach the visual purple, the light is turned off and the examinee looks towards the photometer, which very dimly illuminates a group of dots, or a letter in an unusual position ; the amount of light is slowly increased until the examinee can correctly state the nature of the exhibit and the orientation of it. Theoretically the time taken and the degree of illumination gives the measure of the degree of adaptation to darkness, or in other words the rate of resynthesis of the visual purple. But in practice there are many difficulties, especially in the case of young children, that the more elaborate photometers scarcely justify the cost of them. The luminous hands of a watch may be used in a simple test : the subject is exposed to bright sunlight and then quickly enters a dark room, and is tested for the time he takes to see the hands of the watch held at a measured distance from his face ; and the comparison is made with a known time for normal persons under similar test conditions. A simple test such as this, taken in conjunction with the patient's statement and a consideration of the composition of his diet is sufficient to establish a diagnosis of night blindness which may be further verified by testing the effect of giving large doses of vitamin A.

Bitot's Spots [1] (Pl. I, Fig. 1). These were first described by Bitot [2] in 1863 ; he discovered them in the eyes of some of the inmates of an orphanage in Bordeaux, and they were accompanied by night blindness. They are due to hyperplasia of the conjunctiva over the sclerotics ; thickening and pigmentation of the conjunctiva first appear, so that when the eye moves small ridges appear in the thickened epithelium. With increased hyperplasia Bitot's spots appear as heaped-up masses of keratinized cells. They usually occur over the outer quadrant of the sclerotics, seldom in the inner and probably never in the upper or lower quadrants. Their

[1] *Lancet*, 1939, 1432.

[2] *Gaz. hebd. Med. Chir.*, 10, 284.

PLATE I

FIG. 1.

PIGMENTED CONJUNCTIVA AND BITOT'S SPOT

[*To face page* 80

commonest shape is sub-triangular with the base lying near the cornea-sclerotic junction. They resemble patches of chalk paste, which have been striated with a pin. Sometimes they are broken up into a number of small patches or white striations. Where Bitot's spots occur among school children the thickening and pigmentation of the conjunctiva of the early stages is far more common than the actual spots.

Bitot's spots occur mainly in children of more than two years of age and in adolescents. They appear to be a reaction to a chronic deficiency of vitamin A of moderate degree. They are not an early stage of keratomalacia and seldom lead to that serious condition. Bitot's spots are not always accompanied by night blindness.

Keratomalacia is an acute disease of the eye, and follows extreme deficiency of vitamin A. The metaplasia and atrophy of the epithelium of the conjunctiva also affects the cornea, which becomes vascularized, œdematous and infiltrated with leucocytes, necrosis leads to ulceration, and bacterial invasion continues the destruction of the cornea, produces hypopyon and the result is blindness.

In many tropical countries keratomalacia is most commonly seen among infants of the poorest classes ; it is due to improper food at the time of weaning, or when the mother's milk fails and attempts are made to rear the infant mainly on starchy food such as rice cunjé. Under these circumstances there is a very high mortality rate, and blindness is common among the few who survive. More than 60 per cent. of the blind of Southern India and Ceylon are blind as a result of keratomalacia in infancy.[1]

Treatment by giving vitamin A by mouth (and also by drops in the eye to guard against lowered absorption by the sick child) is rapidly followed by recovery, provided the ulceration is not extreme, and there is no hypopyon.

There is a milder form of keratomalacia characterized by patches of cloudiness or small opaque spots in the cornea.

Teeth. Where signs of vitamin A deficiency occur among the free school children, hypoplasia and mottling of the enamel and patches of dental decay are common. These changes are frequent in the deciduous teeth, and a common type of decay is black in

[1] Nicholls, L., *Cey. J. Sci.*, 1936, IV, 1.

colour, rectangular in shape and sinks deeply into the middle part of the anterior surfaces of the deciduous incisor teeth. Deficiencies in vitamin C and vitamin D values can be excluded in most of these cases, and it appears by process of exclusion that deficiencies of vitamin A and calcium may be the main causes. The diagnosis must be made from fluorosis in which fluorine in drinking-water causes mottling of the teeth (*vide* p. 306).

Skin. Hyperkeratosis with metaplasia and atrophy of the sebaceous glands and plugging of the ducts with degenerate epithelium leads to a dry skin and papular eruption. This most commonly occurs on the exterior aspect of the arms and forearms (*vide* Pl. II, Figs. 2 and 3), but it also appears on the thighs, shoulders, abdomen, back, buttocks and neck. It is seldom seen on the face, and must not be confused with acne. In advanced cases the skin is very dry as the sweat glands are also affected ; the epidermis becomes rough, fissured and scurfy over the greater part of the body ; and this dry state may affect the face. This eruption was first described by A. Pillat[1] in 1929 among Chinese suffering from keratomalacia.

The condition is a " hyperkeratosis follicularis," but this name has been used in reference to similar conditions due to causes other than vitamin A deficiency, therefore it is a generic term. The author [2] in 1933 proposed the term phrynoderma (toadskin) and this term has been widely used in the specific sense. Phrynoderma has been found a very useful sign in nutritional surveys of school children, inmates of prisons, orphanages, asylums and gangs of labourers. The eruption does not occur on the skin of everyone whose diet is deficient in vitamin A, but when it is found in a proportion of persons such as prisoners, on a prescribed diet, it is certain that all on that diet are receiving insufficient vitamin A values for good health.

The Respiratory Tract. The metaplasia and atrophy of the epithelium of the bronchi lead to lowered resistance to pathogenic organisms and may be a primary cause of pneumonia, usually of the peribronchitis type. Atelectasis due to plugging of the bronchi by keratinized cells, and cystic dilations have been described.

[1] *Arch. Ophth.*, 2, 256.
[2] *Ind. Med. Gaz.*, LXVIII, 681.

FIG. 2.

FIG. 3.

PHRYNODERMA (TOADSKIN)

[To face page 82

These effects of vitamin A deficiency are commonest among infants and young children. There are, however, large areas in the tropics where broncho-pneumonia and pneumonia are among the commonest causes of death ; and most of these areas are situated in the hills, where there is a heavy rainfall, the days are hot and the nights are cold and damp, and doubtless the climatic conditions play a great part in determining the prevalence of respiratory infections, yet in many of the areas the diets of the labouring classes (such as those on tea estates) are definitely low in vitamin A values.

The Nervous System. Similar conditions to the spastic paraplegias which occur in animals and chickens on vitamin A deficient diet have not been shown to occur in man. But there is some evidence of myeline degeneration of the cord in human beings on diets deficient in vitamin A.

(1) There is scattered myeline degeneration in the cords of children who have died of malnutrition and shown phrynoderma and keratomalacia during life.

(2) Paresis and ataxia is a rare condition in pregnant and lactating women on diets deficient in vitamin A.

(3) Mellanby has shown that vitamin A has protective values against the poisons of ergot and the lathyrus pea ; and lathyrism (*vide* p. 297) occurs mainly among those on vitamin A deficient diets.

Treatment. The fish-liver oils or concentrates prepared from them, when taken by mouth, rapidly cure the signs and symptoms of vitamin A deficiency, unless very gross pathological changes have taken place. The vitamin can be absorbed through the skin and when digestive absorption is impaired, as in dysenteric children, the oil should be given by inunction.

Methods of Assay

These fall under three headings :

(1) *Biological Assay :*

(*a*) The vitamin A value of the foodstuff being tested is determined by growth response of groups of young rats of the same age (*vide* p. 68).

(*b*) The amount of the foodstuff needed to cure xerophthalmia of vitamin A deficient rats gives its value by comparison with a similar effect of a known amount of β-carotene.

(*c*) Keratinization of the vagina occurs in vitamin A deficient rats, and the cure of this has been made the basis for the determination of the vitamin A values of foodstuffs.

(2) *Antimony Trichloride Test* (*vide* Appendix II, p. 333).

(3) *Spectrophotometic Method.* Vitamin A absorbs ultra-violet rays of a particular wavelength, and the amount of absorption varies with the amount of vitamin A present, and this can be determined by means of an instrument called a spectrophotometer.

Units of Vitamin A

The *international unit* is the vitamin A potency of 0·6γ of pure β-carotene. The original unit was 1γ of a carotene preparation distributed by the Health Organization of the League of Nations, but this was a mixture of α- and β-carotene equal in potency to 0·6γ of β-carotene, hence the present international unit.

A unit of vitamin A, at one time much used in America and called the *Sherman Unit*, is defined as " that amount which when fed daily just suffices to support a rate of gain of 3 gm. per week in a standard test rat during a period of 4 to 8 weeks." This unit is about equal to a vitamin A potency of 1γ of pure β-carotene.

Human Requirements

The requirements of children for growth and development, and of women for pregnancy and lactation, are far greater in kilograms of body weight than the requirements of the ordinary adult.

The Health Organization of the League of Nations[1] recommended that all children between the ages of 2 and 14 years should provided with 1 quart of milk, an egg, servings of green leafy vegetables and butter suited to the size of the child and 3 gm. of cod-liver oil daily. This would provide at least 6,000–8,000 international units of vitamin A daily for each growing child. They recommend 2,000–4,000 international units daily for an adult

[1] League of Nations Report on the Physiological Basis of Nutrition, Geneva 1935.

and at least 5,000 international units for pregnant and nursing mothers. It is certain that in many localities of Europe and America the poorer classes have never been able to give their children a diet containing the luxuries recommended by the authorities of the League of Nations ; and the far lower economic state in vast areas of the tropics does not permit of the practical application of such recommendations by any except a very small percentage of the population.

Edmund and Clemmesen [1] studied the requirements of young men in a state prison in Denmark by determining the amount of vitamin A in their diets and studying their visual adaptation. They concluded that about 1,400 units of vitamin A daily for an adult of 70 kg. was sufficient for normal visual adaptation. Guilbert [2] and his associates showed that sheep, cattle and pigs had almost identical requirements for vitamin A or carotene per kilogram body weight for the prevention of hemeralopia. This is a daily intake of 40–50 units of carotene (25γ–30γ) or 20–30 units of vitamin A per kilogram of body weight. If similar requirements are needed by the human species a man weighing 70 kg. would require daily from 1,400 to 2,000 units of vitamin A, or double that number of units in the form of carotene, as a physiological minimum. Possibly larger quantities than these are necessary for the highest well-being.

Children at the time of weaning and for many years afterwards do not readily convert carotene into vitamin A.

Table XXIV gives the amount of vitamin A or its equivalent in terms of a combination of vitamin A and carotene for children and

TABLE XXIV

	Vitamin A (*units*)*	*Alternative equivalent*	
		Vitamin A (*units*)	*Carotene* (*units*)
Adult	1,800	—	3,600
Children 1–7 years	2,000	1,000	2,000
„ 8–18 „	2,500	1,000	3,000
Nursing mothers	2,500	—	5,000

* International, 0·6γ β-carotene.

[1] "On Deficiency of Vitamin A and Visual Adaptation," trans. Mrs. Clara Packness. Oxford University Press, 1937.

[2] *J. Nut.*, 13, 543.

mothers, or of carotene alone in the case of adults, which may be considered to meet the ordinary requirements of the average tropical population.

The Food and Nutrition Board of the American National Research Council recommend—5,000 I.U. for an adult, 8,000 I.U. during lactation and :

Children less than 1 year	1,500 I.U.	Children 10–12 years	4,500 I.U.
,, 1–3 years	2,000 ,,	,, 13–15 ,,	5,000 ,,
,, 4–6 ,,	2,500 ,,	Others 16–20 ,,	6,000 ,,
,, 7–9 ,,	3,500 ,,		

Storage and Cooking

Vitamin A is fairly stable, being insoluble in water and resistant to the heat of cooking ; no great loss takes place during the usual procedures of preparing food for consumption. Canned food has much the same value as it had prior to canning. Nor is the vitamin A potency of food affected by cold storage. Oxidation, however, slowly destroys the vitamin, and prolonged or repeated cooking will greatly lower the vitamin A value of foods. Foods dried in the sun or dehydrated by other means undergo very considerable losses of this vitamin.

The Vitamin A Value of Foodstuffs

This may be considered under three headings : (1) Comestibles which contain vitamin A and no carotenoids, such as fish-liver oils. (2) Comestibles which contain carotenoids and no vitamin A, such as vegetables. (3) Comestibles which contain both, such as milk and eggs.

TABLE XXV

Vitamin A only

Fish-liver oils :

The content of these ranges from about 10,000 International Units per 100 gm. for codling to 36 million for aged halibut.

Fish-body oils :	*I.U. per 100 gm.*	*I.U. per oz.*
Herring (*Clupea*)	500–6,000	140–1700
Tinned salmon	200–8,000	50–2,300
Sardine	25,000–250,000	7,000–70,000
Shark	50,000–500,000	14,000–140,000

TABLE XXV (*continued*)

Carotenoids only

	I.U. per 100 gm.	*I.U. per oz.*
Cereals:		
Maize (white)	0–60	0–17
Maize (yellow)	300–1,500	80–420
Millets	100–300	27–80
Rice (unmilled)	50	27–80
Rice (milled)	0	14
Wheat	240–820	70–230
Wheat flour (white)	50	14
Pulses:		
Grams and dhals	160–1,000	50–280
Field bean (*Dolichos*)	0	0
Roots:		
Potatoes and yams	16–500	5–140
Gourds:		
White gourds and marrow	0	0
Ridge and bitter gourds	100–1,500	27–420
Red pumpkin	160	50
Snake gourd	100–1,500	27–420
Vegetable fruits:		
Beans (pods) (French)	330–700	90–200
Brinjal	10	3
Carrot (red)	3,300–15,000	900–4,200
Carrot (white)	160–250	50–70
Chilli	330–1,400	90–400
Drumsticks	250	70
Ladies fingers	100	27
Plantain (unripe)	80	24
Tomatoes (whole)	16,000–70,000	5,000–20,000
Leaves:		
Deep green leaves	2,400–20,000	700–5,600
White cabbage leaves	50	14
Dessert fruits:		
Apricots	3,300–8,200	900–2,300
Banana	200	55
Cape gooseberry	5,000	1,400
Dates (preserved)	1,000	270
Guava	250	70
Mango	3,300–11,000	900–3,400
Papaya	3,300	900
Rose hips	8,200–14,000	2,300–4,000

TABLE XXV (*continued*)

Carotenoids only (*continued*)

	I.U. per 100 gm.	*I.U. per oz.*
Nuts and oil seeds:		
Cashew nuts	160	50
Coconut	0	0
Gingelly seeds	160	50
Mustard seeds	400	220
Red-palm oil	40,000–400,000	11,000–110,000
Miscellaneous:		
Jaggery	160	50
Saffron (*Crocus sativis*)	0	0
Tea leaves	160,000–800,000	45,000–220,000
Yeast	80	24

Foodstuffs with both Vitamin A and Carotenoids

	Vitamin A		*Carotene*	
	I.U. per 100 gm.	*I.U. per oz.*	*I.U. per 100 gm.*	*I.U. per oz.*
Dairy products:				
Milk (cow or buffalo)	130–250	27–70	100–160	30–50
Milk (human)	160–270	50–78		
Butter	1,000–8,000	270–2,400	30–3,000	8–850
Cheese	5,000	1,400		
Eggs:				
Hens (whole)	700–1,200	20–340	1,300–2,000	370–560
Flesh:				
Fish	50	14	30	9
Beef	60	17	very variable	
Mutton	30	10		
Liver	10,000–160,000	2,700–45,000		
Turtle oil	40,000	1,1000		

VITAMIN B COMPLEX

The vitamin B complex includes thiamine, riboflavin, pyridoxine, biotin, pantothenic acid and para-aminobenzoic acid, and it is convenient to include nicotinic acid in this group.

VITAMIN B_1

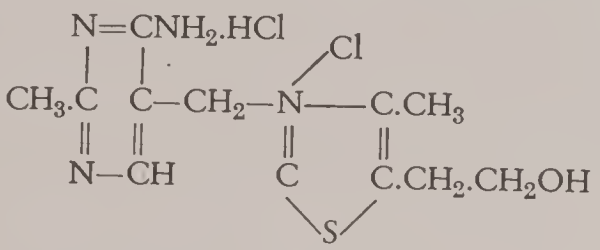
Thiamine (Aneurin)

Vitamin B_1 was named " aneurin " by Professor Jansen, but the American Medical Association objected to the name because it carried an implication of therapeutic utility. The name " thiamine," indicating that the vitamin contains sulphur, has come into use

pending a decision from the International Committee on Nomenclature.

Isolation of Thiamine. More than a quarter of a century elapsed after Grijns had suggested the existence of an anti-neuritic substance in rice millings before it was isolated as a crystalline preparation. Very appropriately this was done by two other Dutch investigators, Jansen and Donath in 1926.

Structure and Synthesis. Thiamine hydrochloride has the composition $C_{12}H_{18}N_4OSCl_2$. Its chemical structure is as follows :



Thus its structure consists of two nuclei—a pyrimidine and thiazole, held together by a methylene bridge uniting a carbon atom of the former to a nitrogen atom of the latter. This vitamin is the only known substance produced by living matter which has a thiazole ring.

Buchman [1] in America and Grieve [2] in Germany, working independently, were the first to synthesize this vitamin, their reports were published in 1936.

Properties. Thiamine chloride occurs as spicular crystals (Pl. III, Fig. 4). The melting-point of the chloride from rice millings is 246° C. whereas that of the synthetic chloride is 233° C. It is suggested that the former is a mixture of two stereoisomers of equal potency but having different melting-points. Its two properties of great practical importance are : (1) its great solubility in water (1 in 20) and hence it is liable to be leached from foods when they are being washed or boiled, (2) the bond between its two nuclei is somewhat weak, and this renders it liable to destruction especially in an alkaline medium.

Thiamine exists in the body in two forms, partly in the free state, but to a greater extent as the pyrophosphate.

[1] *J. Amer. Chem. Soc.*, 58, 1803.

[2] *Z. physiol. Chem.*, 242, 89.

Action. This vitamin plays a part in carbohydrate metabolism both in plants and animals, and its important function is to remove certain products of carbohydrate metabolism. Lactic acid is one of these metabolites and dehydrogenizing ferments, of which compounds of nicotinic acid and riboflavin act as prosthetic groups, convert lactic acid to pyruvic acid :

$$\underset{\text{Lactic acid}}{CH_3CHOHCOOH} - 2H \rightarrow \underset{\text{Pyruvic acid}}{CH_3COCOOH}$$

Thiamine pyrophosphate is the prosthetic group of an enzyme, the other group being a specific protein, each alone has no enzyme action, but in combination they bring about the decarboxylation of pyruvates with the evolution of CO_2, the first stage of this is as follows :

$$\underset{\text{Pyruvic acid}}{CH_3COCOOH} \rightarrow \underset{\text{Acetaldehyde}}{CH_3CHO} + CO_2$$

Pyruvates and lactates accumulate in the blood and tissues of thiamine deficient animals and in patients with beriberi ; the pyruvates accumulate because they are not destroyed and the lactates because the accumulation of pyruvates inhibits dehydrogenase.

Pyruvic aldehyde, also known as methyl glyoxal (CH_3COCHO) is a metabolite in a stage of less oxidation than pyruvic acid. Some authorities, mainly the Japanese, assert that the accumulation of glyoxal in the tissues in cases of thiamine deficiency has a marked toxic effect, and also that its excretion in the milk of thiamine deficient lactating women plays a causal part in infantile beriberi.

Thiamine pyrophosphate, being the prosthetic group of a decarboxylating enzyme, has been called co-carboxylase ; but objection had been taken to this as being too committal, because there is some evidence that thiamine may enter into other enzyme systems, such as in conjunction with a specific protein to form an oxidase.

It has been suggested that the pathological effects of thiamine deficiency are due to the accumulated metabolites—lactate, glyoxal and pyruvate ; but no one has succeeded in producing polyneuritis (the chief sign of thiamine deficiency) by the injections of these.

PLATE III

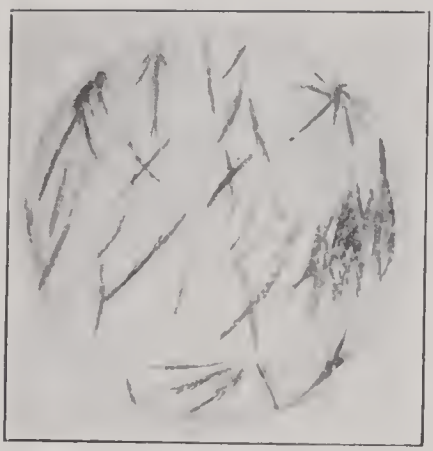


FIG. 4.
THIAMINE CRYSTALS

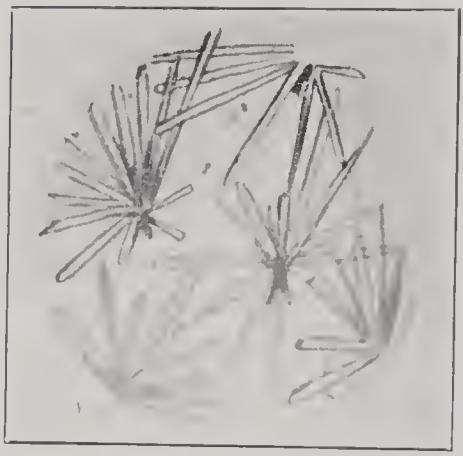


FIG. 5.
RIBOFLAVINE CRYSTALS

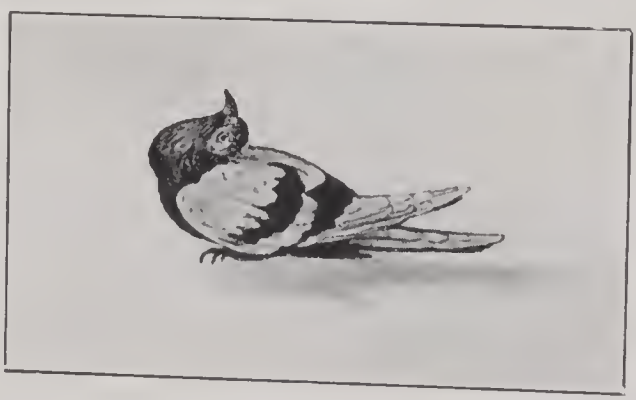


FIG. 6.
PIGEON WITH POLYNEURITIS

[*To face page* 90

This, however, is not evidence that they are not the cause of polyneuritis ; the accumulation of the products of any enzyme action inhibits the action ; and nascent metabolites within a cell may have a far greater effect than when they are circulating in the blood stream.

Effects of Deficiency of Thiamine in Animals

All birds need thiamine for growth and health. Pigeons, fed on highly milled rice and water only, develop signs of polyneuritis in three to four weeks, the most characteristic sign being head retraction, the head falling and lying on the back of the bird (Pl. III, Fig. 6). Sometimes the head falls forwards and is supported by the beak resting on the floor of the cage. All birds do not show signs of polyneuritis when fed a vitamin B_1 free diet, many (about 50 per cent.) die suddenly, apparently from heart failure.

Rats given a diet entirely free from thiamine die within one or two weeks without showing marked clinical signs, but when there are minimum quantities of thiamine in the diet they show polyneuritis with convulsions in 6–8 weeks. The clinical signs are lameness of the hind and fore-limbs, inco-ordination, rolling movements, nystagmus and convulsions. A constant sign of thiamine deficiency in rats is bradycardia. The rate of the normal heart beat of the rat is about 500 per minute, and this falls to 300–350. An electrocardiograph is needed to count the rapid pulse rate of the rat.

The growth of young rats soon ceases when they are fed thiamine-deficient diets ; and a daily quantity which appears to be sufficient for good health in older rats is not sufficient for good growth.

The dog has been used in experimental work and on thiamine-deficient diets develops a spastic paralysis.

A conditioned deficiency of thiamine has been recorded among the foxes on fur farms, it is Chastek's paralysis, and is the result of a diet containing 10 per cent. or more of uncooked fish. It is a pure thiamine deficiency because it can be prevented or cured by giving small doses between meals when there is no fish in the stomach, and by giving very large doses with the meals. The substance which prevents the absorption of or destroys the thiamine is in the viscera and not in the flesh of the body of the fish.

A common symptom in all thiamine deficient animals is anorexia, and as this may lead to a refusal of food, animal experiments are apt to be complicated by the factor of starvation.

Thiamine is produced in the rumen of cattle and other ruminants, possibly by bacterial action, hence these animals do not suffer from a deficiency of this vitamin.

Effects of Minor Thiamine Deficiency in Man

Animal experiments suggest that a child receiving insufficient thiamine will have some stunting of growth, although there may be no marked signs of ill health.

The clinical picture in more definite cases is referable to loss of tone of the gastro-intestinal tract, this is not a sequence of general debility but is due to specific changes in the stomach and intestines leading to loss of appetite and sluggish peristaltic movements. The child becomes pale and fretful from loss of appetite and constipation. Much the same occurs with adults, but in this case there is usually distention and flatulence. Unless urinary tests for the excretion of thiamine are carried out, the diagnosis is never more than presumptive, but when tone and health rapidly return on large doses of thiamine (1 mg. or more) it is reasonable to accept the therapeutic evidence. Some clinicians have pointed to the mental outlook in thiamine deficiency, and suggest that the resulting irritability, depression and quarrelsomeness may be a cause of strikes and other labour disputes.

Effects of Major Thiamine Deficiency in Man—Beriberi

Extreme deficiency is followed by the disease beriberi. In most cases, possibly in all, there are other deficiencies which contribute to the clinical picture ; and there may be stresses such as fatiguing labour or mental anxiety which help to start the onset of the disease.

The earliest sign is weakness of the legs, often accompanied by epigastric fullness and discomfort. Numbness and formication appear in the lower and upper limbs, and when the calves are squeezed they are found to be abnormally tender. (Though not pathonomonic, this is a useful test when examining groups of labourers.) Two early signs are pretibial œdema and some breath-

lessness. The knee jerks may be exaggerated at first and disappear in a few days. The " squatting test " is useful in the early stages of the disease, the patient with his hands on the top of his head cannot assume a squatting position, with the use of his hands he can take up this position but cannot rise from it unless allowed to use his hands, and then he assumes the erect posture by what has been called " climbing up his own legs." As the disease progresses the patient's gait becomes high-stepping, and he uses a stick placed well in front of him and forming with his legs a tripod to support his weight.

There may be marked ankle drop. The numbness and the weakness of the arms and hands renders difficult the picking up of small objects such as grains of rice ; and the movements in attempts to button the coat are awkward and fumbling.

The heart is often seriously affected in beriberi, this is due to œdema and myocardial degeneration, and not to degeneration of the nerves of the heart. The right side of the heart is usually more detended than the left. The clinical signs are those of a failing heart, there are pulsations visible over the precordial area, and over the jugular veins, the pulse rate is increased (and this is in contrast to the bradycardia of thiamine-deficient rats), and the heart is dilated. Sudden death from heart failure is frequent among beriberi patients.

Deaths on the streets of oriental countries are not infrequently due to overexertion in the early stages of beriberi.

There may be extreme œdema affecting the whole body and giving the patient a bloated appearance, when this is present the term *wet beriberi* is used in contrast to *dry beriberi* in which there is emaciation due to wasting of the muscles but little or no œdema. There are intermediate forms between dry and wet beriberi. There is some evidence that the œdematous type is mainly or partly due to the diets having been deficient in proteins.

Infantile Beriberi. This is a common cause of infantile deaths in many parts of the tropics, especially in Egypt, Philippines and certain Pacific islands.

Infantile beriberi is due to the maternal diets being deficient in thiamine ; the effect on the infant may have started in utero, but

the onset of the disease is usually six to twelve weeks after birth and is mainly due to the milk being deficient in the vitamin. About 50 per cent. of the mothers themselves show signs of hypovitaminosis. Japanese workers have proposed that the disease is due to poisoning by methyl glyoxal of the mother's milk, but this cannot be accepted on the present evidence.

In a typical case there is a sudden onset of severe vomiting and the patient has a rapidly increasing generalized œdema. The only sign of nerve involvement is aphonia, possibly due to pressure on the recurrent laryngeal nerve by a dilated left auricle, there is dyspnœa followed by convulsions when sudden death of the infant may occur. The aphonia, œdema and convulsions may be considered diagnostic, but many cases are without these three signs. The only sign shown by some of the infants is convulsions followed by death ; in other cases there is progressive weakness and wasting with frequent attacks of vomiting.

C. W. Brey [1] made an interesting study of infantile beriberi in Nauru in the Pacific. "Toddy," the fermented sap of the coconut palm, was widely used by the islanders until it was prohibited by Government order. This was followed by much infantile beriberi. Toddy has a milky appearance due to suspended growing yeast which is rich in thiamine, and a teaspoonful of toddy given twice a day to an infant is sufficient to prevent beriberi.

In countries where definite infantile beriberi does not occur, yet there may be much thiamine hypovitaminosis among mothers and infants. Human milk has 0·15γ of thiamine per gm., which is low compared with cow's milk, which has 0·4γ per gm. Even women who appear to be fairly well fed may be excreting milk with a thiamine content much below normal, in these cases the suckling infant does not thrive, has a pasty appearance, gains weight not at all or very slowly and has bouts of vomiting with constipation or diarrhœa. When the mother is given large doses of thiamine (1–2 mg. daily) the infant recovers rapidly.

Conditioned Deficiencies. There is therapeutic evidence that gastro-intestinal disorders may lead to failure of absorption or utilization of thiamine. The gastritis of heavy drinkers, either primarily or

[1] *Proc. R. Soc. Med.*, 23, 741.

because it leads to lost or perverted appetite, is the forerunner of alcoholic neuritis. The vomiting of pregnancy may lead to signs of thiamine deficiency. Neuritis may arise during the course of typhoid or chronic dysentery, which is relieved by parenteral injections of thiamine.

Storage and Excretion of Thiamine. This vitamin occurs throughout the body but is highest in the liver, kidney, heart and brain. The body cannot maintain large stores against future needs, possibly because this vitamin is easily destroyed by oxidation. On deficient diets the amount of thiamine in the body falls rapidly and the main reserves are depleted in about 5–6 weeks, but minimal amounts are retained persistently. When large amounts of thiamine are taken, the excess is partly destroyed in the body by oxidation, and partly excreted in the urine. Changes in the intake of thiamine are reflected in the urinary output, hence a low urinary excretion is an index of deficiency.

Laboratory Tests for Thiamine Deficiency. Harris and Leong [1] were the first to use *urinary tests* for thiamine deficiency. They estimated the amount of the vitamin in the urine by means of the bradycardia test with rats. They showed that the amount of vitamin in the urine varied with the amount taken in the diets, and also that those on diets deficient in thiamine responded to a test dose by higher retention than in the case of those on a sound diet. More recently the " thiochrome reaction " has been used, but at present the tests are too complicated for ordinary hospital practice.

The amount of thiamine excreted daily is given in Table XXVI.

TABLE XXVI

	Amount in γ daily
Those on a satisfactory diet . . .	40–120
Those on diets moderately deficient .	15–20
" " very " .	6–10

Pyruvic Acid can be roughly determined in the blood and urine by its bisulphite binding property.[2] Platt and Lu [3] have shown that in severe cases of beriberi the amount was fairly parallel with

[1] *Lancet*, 1936, 886.

[2] See *Biochem. J.*, 1939, 33, 249.

[3] *Quart. J. Med.*, 5, 355.

the degree of the clinical manifestations. Unfortunately the test is not specific and is useless in mild degrees of deficiency.

Treatment of Thiamine Deficiency. Thiamine can be given by mouth, subcutaneously or intravenously. The usual therapeutic doses is from 1 to 5 mg. But large doses such as 50 mg. may be given without ill effects. Yeast may be given as a powder or in the form of marmite.

An excellent soup for hospital practice among the labouring classes can be made from rice bran. The bran is placed in a muslin or calico bag and soaked and kneaded into warm water, when much of the vitamins and starch and some of the proteins is dissolved or leached out, the bag retains the coarse fibrous bran and such undesirable matter as phytin. The soup is completed by cooking this bran extract with dhal, vegetables and suitable seasoning.

Methods of Assay. Pending the discovery of precise chemical methods, the determination of the amount of thiamine in foods has been by biological methods, and various units have been used for recording the amount of the vitamin present in any particular foodstuff. Numerous difficulties are associated with bioassays and are reflected in the many methods which have been pursued ; and these may be divided into seven groups :

(1) Based on the prevention of polyneuritis.
(2) Based on the cure of polyneuritis.
(3) Based on the cure of bradycardia in rats.
(4) Based on weight maintenance.
(5) Based on restoration of weight.
(6) Based on the rate of growth.
(7) Based on the requirement of certain plants and micro-organisms.

In some of these groups there is no generally accepted fixed standard and various animals may be used such as fowls, pigeons, rice birds (munias) or rats. It is not surprising, therefore, that bioassay has lacked precision and some of the results given by different workers have not been in very close agreement. Several chemical methods have been proposed and perhaps at the present time the best of these is the *thiochrome method.*

The test is complicated, but the general principle is to extract

the thiamine from the foodstuff by prolonged action with the acidulated alcohol or other solvent, adsorb the vitamin on Fuller's earth or other adsorbent, elute it from the earth and oxidize it by ferricyanide to thiochrome, which has a bluish fluorescence. A standard solution of pure thiamin is likewise oxidized, and the amount of thiamin extracted from the foodstuff is determined by comparing the degree of fluorescence of the two solutions with a fluorometer.

Units of Thiamine

Several units based on bioassay have been widely used, but for various reasons they are somewhat uncertain quantities.

The Smith Unit was laid down as that amount required to cure every polyneuritic rat in the series used.

The Chase-Sherman Unit is defined as that amount of thiamine per day required by a rat for growth at the rate of 3 gm. per week during an experimental period of from 4 to 8 weeks.

The Chick-Roscoe Unit is the amount of thiamine per day required by a rat for growth at the rate of 10–14 gm. per week over a period of five weeks.

The original International Standard Unit of thiamine was 10 mg. of acid clay adsorbate of vitamin B_1 from an extract of rice millings produced according to the technique of Seidell as modified by Jansen and Donath.

Such units have been very necessary prior to the isolation of the vitamin in a pure form, but since pure crystalline thiamine has been prepared there is need no longer for these units and the quantity of thiamine present in any substance can be referred to in terms of micrograms (γ). The following gives roughly the amounts of the units mentioned above in micrograms :

Smith Unit	6·7γ
Chase-Sherman Unit	1·7γ
Chick-Roscoe Unit	3·3γ
International Unit	3·3γ

Human Requirements of Thiamine

The Hygiene Section of the League of Nations supported a value of 300 International Units as the minimum daily requirement for a

man, this is about 1,000γ. From their experience in the East Indies the Dutch consider 150 I.U., which is half the above figure, the minimum requirement for the Javanese. The American National Research Committee recommend 1,500γ per adult and 1,900γ during pregnancy and lactation as desirable intakes.

Since the revelation that the main function of thiamine is to act as the prosthetic group of an enzyme, which is concerned with carbohydrate metabolism, it has been realized that the requirement of the body for thiamine will vary with the intake of carbohydrate. Indeed, this is in accordance with past experience that beriberi has always followed diets rich in carbohydrates especially among gangs of labourers.

Cowgill [1] scrutinized 180 human dietaries and showed that beriberi producing diets had a low ratio between the vitamin content and the caloric value. William and Spies [2] went a step further and classified diets on a ratio between the thiamine and the non-fat calories. Using their preferred values (these are used in Tables L to LXII on pp. 182–201) for the thiamine content of various foods they showed that this ratio of beriberi-producing diets is near 0·3.

The use of their ratio is far sounder for determining human requirements of thiamine than postulating a definite amount for all types of diets.

Let us consider three diets, such as are not uncommon in Southern Asia :

(A) A diet of 2,300 calories suitable for a sedentary worker and consisting of lightly milled parboiled rice with a small amount of fish and vegetables.

(B) A diet of 2,300 calories as taken by many sedentary workers and consisting of highly milled raw rice with a small amount of fish and vegetables.

(C) A diet of 3,100 calories as is not infrequently taken by labourers and consisting of highly milled raw rice with fish and vegetables.

Table XXVII gives the thiamine non-fat caloric ratio of the three diets :

[1] " Vitamin B_1 Requirements of Man." Yale University Press (1934).
[2] " Vitamin B_1." The Macmillan Co., New York (1939).

TABLE XXVII

Diet	*Thiamine*	*Non-fat calories*	*Th : N.F.C.*
A	1,000γ	1,800	0·55
B	570γ	1,800	0·32
C	635γ	2,500	0·25

As regards thiamine, diet A is satisfactory ; diet B is borderline, but in the case of a sedentary worker will probably not lead to beriberi although the consumers may be in a state of sub-clinical deficiency ; diet C is a beriberi-producing diet although it contains more thiamine than diet B.

This Th : N.F.C. ratio is applicable only for diets in which the staple articles are of vegetable origin. The ratio given by the fermented milk diet of the Masai and the meat diet of Eskimos are far too high, being two or more, because of the very low content of carbohydrates in such diets.

The following gives the value in thiamine in respect of the Th : N.F.C. ratio for most tropical diets :

Ratio below	0·3	Beriberi-producing diets.
,, between	0·3–0·35	Borderline and too low.
,, ,,	0·35–0·45	Sufficient for light labour.
,, above	0·45	Desirable.

Effect of Storage and Cooking on Thiamine

Cereals stored for one year lose very little thiamine provided they have kept well, that is, have not been attacked by bacteria or insects. After longer storage the thiamine slowly decreases.

It is an easily oxidized vitamin especially in alkaline medium. During the ordinary processes of canning, when the foodstuff has a faintly acid reaction, not more than 20 per cent. is lost, but when the foodstuff is faintly alkaline 40 per cent. or more may be lost.

Some cooking processes may leach out the vitamin or destroy it at high temperatures (*vide* p. 70).

Thiamine in Foodstuffs

The vitamin is so widely distributed in naturally occurring foods that there is never likely to be a shortage of it in diets unless it has

been removed by artificial means. All the cereal grains such as rice, wheat, oats and millets are comparatively rich in vitamin B_1, which, however, is not evenly distributed throughout the grain but is concentrated in the germ and pericarpal layers. These parts are removed from the rice in the form of millings (fannings) when it is milled to prepare a white rice for the markets (*vide* p. 208). The bran and pollards of wheat which are removed from the grain in the preparation of white flour contain the greater part of the thiamine (*vide* p. 206).

In many parts of the world the staple cereal forms 60 per cent. or more in terms of calories of the diets of the labouring classes, such diets are seldom adequately supplemented with other foodstuffs and much ill health and even frank beriberi follows the use of them.

Table XXVIII shows the comparative quantities of thiamine in various foodstuffs (see also Tables L–LXII).

TABLE XXVIII

More than 3γ per gm.		*2–3γ per gm.*	*1–2γ per gm.*	*Less than 1γ per gm*
Yeast	20–70γ	Unmilled rice	Eggs	Highly milled rice
Rice millings		Parboiled rice	String beans	White flour
Pollards		Maize	Green peas	Roots,
Offals		Soya bean		Vegetable fruits
Peanut	8γ	Dhals		Leaves
Mongo bean	4γ	Grams		Fruits
Wheat		Dried milk		Milk
Barley		Cheese		Fish
Millets				Meats
Pork				
Duck's eggs				
Oatmeal				
Liver				

CHAPTER VI

VITAMIN B COMPLEX (*contd.*)

RIBOFLAVIN

Synonyms: Lactoflavin, Vitamin B_2. Vitamin G of American Literature.

Early experiments made to demonstrate the anti-neuritic factor (vitamin B_1) showed inconsistencies especially in respect of the growth and general health of the animals; and about 1920 it became apparent that many of the preparations, tested with the basal diets, contained more than one vitamin.

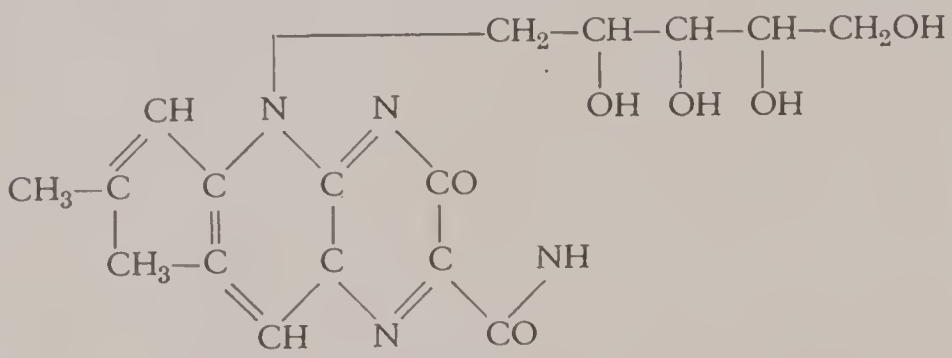
It had been discovered that the anti-neuritic factor was easily destroyed by heat, and in 1926 Smith and Hendrick [1] showed that yeast, after it had been autoclaved for six hours at 15 lb. pressure, still contained a growth-promoting factor for rats. Also it was found that foodstuffs might be rich in one factor but not in the other, for instance, liver is a good source of the growth-promoting factor, but a poor source of the anti-neuritic factor. These and other pieces of evidence were conclusive of the existence of at least two factors. Sherman [2] had suggested the letters F and G for the two factors, but the Americans continued to call the heat labile factor vitamin B_1 and the heat stabile factor vitamin G. In Europe the designations B_1 and B_2 have been preferred. The confusion does not cease here because there are other heat stabile factors, and hence some authors speak of the vitamin B_2 complex, but this is unnecessary, especially as at least one number of the complex has been named in the B series, namely, vitamin B_6. It is simpler to consider riboflavin and vitamin B_2 as synonymous, and other heat stabile factors as members of the entire vitamin B complex.

Isolation of Riboflavin. As long ago as 1879 Wynter Blyth [3] isolated a pigment in an impure state from milk and named it "lactochrome." Warbury and Christian [4] in 1932 isolated an enzyme from yeast and named it "yellow respiratory pigment"

[1] *Public Health Rep.* (1927), 41, 201.
[2] *J. Chem. Ed.* (1926), iii, 1241.
[3] *J. Chem. Soc.*, 35, 350.
[4] *Biochem. Zeitschr.*, 254, 438.

because of its oxidizing action. They showed that it consisted of a protein and a green-yellow fluorescent pigment. Kühn [1] and his associates were the first to isolate the pigment in a pure state and to identify it as a vitamin because of the growth-promoting effects. They suggested the group name "flavin." At one time the flavins were named after the sources from which they were isolated, such as lactoflavin and ovoflavin. It is now known that they are identical and that the carbohydrate d-ribose is present in their molecule, hence the name riboflavin.

Structure and Synthesis. Riboflavin has the empirical formula $C_{17}H_{20}N_4O_6$. Its chemical structure has been established by Kühn and his co-workers as follows :



Riboflavin and various analogues have been synthesized starting from d-ribose. Some of the analogues have biological activity, but none of them has more than half the activity of riboflavin.

Properties. Riboflavin crystallizes as yellow-brown needles having a melting-point of 293° C. (Pl. III, Fig. 5). It is slightly soluble in water (1 in 200). It is destroyed by long exposure to the direct rays of the sun. But the drying of foodstuffs, such as grain, by the heat from the sun does not greatly affect their content of the vitamin. Alkalis have a destructive effect on it but it is very stable in an acid medium. Riboflavin has a bitter taste.

Action. On phosphorylation it forms an ester which, in combination with adenylic acid, acts as the prosthetic group of a yellow enzyme. The other part of the enzyme is a protein. The two are easily separated by dialysis, and separately have no activity.

There is evidence that riboflavin may combine with more than one enzymatic protein. The flavoproteins act as dehydrogenases

[1] *Ber. Deut. Chim. Ges.*, 67, 892.

PLATE IV

FIG. 7.

ANGULAR STOMATITIS

FIG. 8.

POLYAVITAMINOSIS

[To face page 103

and remove many metabolites by destroying them, such as succinic acid, acetaldehyde, *d*-amino-acids, xanthine, glutamic acid and even alcohol.

There is also evidence that they co-operate with other vitamins in many actions, thus they act with an enzyme, in which a nicotinic acid amide compound is the prosthetic group, to reduce lactic acid to pyruvic acid, and then the latter acid is destroyed by an enzyme of which thiamine pyrophosphate is the prosthetic group.

Effects of Deficiency of Riboflavin in Animals

Partial deficiency of riboflavin in the diets of rats leads to delayed growth, alopecia with dermatitis of the denuded areas, conjunctivitis, keratitis, premature senility ; and some rats develop cataracts. After prolonged deficiency there is myelin degeneration of the peripheral nerves and posterior columns of the cord.

Animal experiments have shown the important part riboflavin plays in the economy of the utilization of food in building up body tissues. In one experiment rats on a diet, deficient in riboflavin, each gained on an average 6·1 gm. in weight in 125 days, whereas their litter mates during the same period on the same amount o food plus 20γ of riboflavin gained 61·3 gm.

Sarett, *et al.*,[1] found that riboflavin excretion by dogs and rats varied inversely with the protein intake, and that protein deposition was necessary for riboflavin retention in the liver.

Sure [2] has shown that there is a definite thiamine-riboflavin interrelationship and that chronic thiamine deficiency produces great losses of riboflavin in the urine.

Recent work [3] with animals has shown that riboflavin deficiency in the mothers leads to deformities of the bones of the offspring. This deficiency may be a cause of deformities of the jaws among children of the indigent classes.

Effects of Deficiency of Riboflavin in Man

A deficiency of this vitamin causes the "*sore mouth*" so common among the labouring-class children of many parts of Asia, and this

[1] *J. Nut.*, 25, 173. [2] *J. Nut.*, 27, 447.
[3] For references, see *J. Nut*, (1944), 27, 477.

sign has been widely used in nutritional surveys ; it includes angular stomatitis (Pl. IV, Fig. 7), cheilosis and superficially eroded tongue, which in the advanced state may be markedly fissured. Patients complain of soreness of the mouth, and a few of them of burning sensation on swallowing, indicating that the erosion has extended to the pharynx, this extension occurs far more often in pregnant or lactating women than in other sections of the population.

Perhaps the sign next in frequency is *scrotal dermatitis*, starting with itchiness and scaliness, and in its more advanced state the scrotum is enlarged from subcutaneous œdema, and patches of superficial ulceration are scattered over it. A greasy dermatitis around the naso-labial folds has been recorded from India.

Many ocular symptoms and signs have been attributed to riboflavin deficiency because recovery follows the administration of this vitamin and in some cases the signs are similar to those which occur in riboflavin deficient animals. The clinical pictures from different countries show variations, and this may be due to various other deficiencies accompanying that of riboflavin.

American observers were the first to draw attention to various eye conditions. Photophobia and dimness of vision not corrected by lenses are the most frequent symptoms. Vascularization of the sclerotic has been attributed to riboflavin deficiency. It takes place near the corneal margin and extends on to the cornea, loops of newly formed capillaries appear, and although in the early stages a lens or even a slit lamp may be required to reveal them, yet in the later stages the network of capillaries around the cornea may be very marked indeed. These changes may be accompanied by roughness of the eyelids, burning sensations of the eyeball and much visual fatigue. Lacrymation occurs and may be extreme. Keratitis, corneal opacities or iritis may occur. Cataracts have been attributed to this deficiency without much evidence apart from analogy, in that they are known to occur in riboflavin-deficient rats.

Most of the advanced cases of riboflavin deficiency in human beings have been recorded as a result of diets given in the treatment of peptic ulcer, colitis and other alimentary disorders. Further evidence is required before the reported eye conditions can be finally accepted as due to riboflavin deficiency.

Where children of the labouring classes show signs of this deficiency, and it is also found that they are markedly smaller at all ages than the children of the wealthier classes of that country, it is not improbable that riboflavin deficiency is one of the factors affecting their growth, because of poor utilization of the food consumed.

Laboratory Test for Riboflavin Deficiency

It has been recorded by Sebrell, Swaminathan [1] and others that when a test dose of 0·2–0·5 mg. of riboflavin is given to a normal person on a more or less satisfactory diet from 50 to 80 per cent. is excreted in the urine in the following 24 hours, whereas in persons showing signs of ariboflavinosis only 10–20 per cent. of such a test dose is excreted. Unfortunately the tests are at present too complicated for routine medical practice.

Estimations of Riboflavin in Foodstuffs and Urine

There are two general methods :

(*a*) *Biological methods.* There are two, the first is based on the minimum amount needed for good growth of young rats, and the second is bacteriological using *Lactobacillus casei* which needs riboflavin for its growth.

(*b*) *Physico-chemical methods.* There are several of these, they are complicated, and either a colorimeter or fluorimeter is used to determine the degree of yellow-green colour or the fluorescence of the extracts.

Unit of Measurement of Riboflavin

The original unit was proposed in America where it was referred to as a unit of vitamin G and called the *Bourquin-Sherman Unit.*[2] It is " that amount which when fed daily to a standard test animal (a rat) under the conditions described [3] results in an average gain of 3 gm. per week during the test period." The provisional unit is between 3 and 5γ of riboflavin. The present unit is the microgram (γ) of the vitamin.

[1] *Ind. Med. Gaz.*, LXXVII, 650.
[2] *J. Am. Chem. Soc.*, **53**, 3501.
[3] " Sherman's Chemistry of Food and Nutrition," 5th ed., Macmillan, p. 409.

Daily Requirements of Riboflavin

These are not definitely known, but Table XXIX gives amounts which are safe and probably somewhat larger than are needed for good growth.

TABLE XXIX

	Mg.
Children under 6 years	1·0
,, 6–12 years and adults . . .	1·5

Effects of Storage and Cooking

The riboflavin content of foods is very little affected by ordinary storage or cooking. Prolonged exposure of foods to the sun reduces the amount of the vitamin because of the destructive effect of ultra-violet light. Probably this is the reason why some samples of dhal have been found to contain very little riboflavin ; some dhals are prepared by exposure to the sun and repeated kneading in of oils, the rays of the sun destroy the vitamin near the surface of the grain and each oiling brings more to the surface for destruction.

The use of soda in cooking has a destructive effect on riboflavin

TABLE XXX [1]

Riboflavin in Foodstuffs

Foodstuffs of Vegetable Origin :	*γ per gm.*	*γ per oz.*	*Pulses :*	*γ per gm.*	*γ per oz.*
Cereals :			Dhals . .	0·4–2·0	11–56
Barley . . .	0·5	14	Grams, Soya bean, Peas (dry), Peanuts (*Arachis*)	2–3	56–84
Bread (wholemeal) .	1·0	28			
Bread (white) .	0·4	11			
Maize . . .	0·5	14			
Millets :			*Roots :*		
Ragi, Cholam, Cambu . .	0·7	20	Potato, yam and other roots . .	0·2–0·6	6–17
Rice (highly milled)	0·4	11	*Vegetable fruits* .	0·3–1·0	8–28
Rice (lightly milled)	1·0	28	*Vegetable leaves* .	0·5–1·5	14–42
Rice (parboiled) .	1·0	28	*Dessert fruits* . .	0·6	17
Wheat . . .	1·2	33	Coconut . .	0·6	17
			Yeast (dried) . .	20–60	560–1180
Foodstuffs of Animal Origin :					
Cheese . . .	1·5–4·0	42–110	Liver . . .	4–35	110–980
Fish (lean) . .	1·0–2·0	28–56	Meat . . .	2·0	56
Fish (fat) . .	5·0	140	Milk (cow's) . .	1·5	42
Fish (roes) . .	4–17	110–476	Milk (powder) .	15	420
Fish (sprats) . .	5·0	140	Milk (human) .	0·4	11

Grain which is sprouted for a week produces 5–10 times its original amount of riboflavin.

[1] Partly from *Nut. Abs. and Rev.*, 9, 820.

Riboflavin in Foodstuffs

The vitamin is widely distributed in foodstuffs, but unfortunately the present methods of assay have given somewhat inconsistent results in the hands of various workers ; and apart from this the amounts in different samples of the same foodstuff may vary within very wide limits. Consequently the figures given in Table XXX are rough averages.

NICOTINIC ACID (Nicotinamide)

Synonyms : Vitamin PP. Niacin. Niacin amide.

The disease pellagra was first described in 1735 by a Spaniard named Casal and he attributed it to faulty nutrition ; and since his time the opinion of most students of the disease have been in agreement with this, except for a brief period, following the work of Pasteur, when many investigators became microbe hunters and sought an infectious cause for this disease.

Goldberger has been the most persistent student of the disease since his appointment in 1913 by the U.S.A. Bureau of Public Health to investigate a very serious outbreak of pellagra in the Southern States. He soon came to the conclusion that it was of dietary origin, but at first he thought it might be a protein or amino-acid deficiency because the disease can be cured by some diets of high protein value. Voegtlin [1] with others in 1920 dispelled this " protein theory " when they showed that 95 per cent. alcoholic extract of liver in large daily doses was curative for pellagrins, although the extract contained very little protein. Goldberger [2] and his associates (1926) showed that pellagra could be effectively treated with an acid extract of yeast ; and the existence of a non-protein " P-P " (pellagra-preventive) factor was postulated, and it became customary to refer to this as vitamin PP.

Much confusion reigned because most of the work on the subject was being done with rats, and a dermatitis and other signs which are now known to be due to riboflavin deficiency were believed to be analogous with the pathological changes of human pellagra.

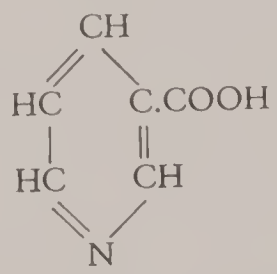
[1] *Bull. U.S. Hyg. Lab.*, No. 116.
[2] *Pub. Health Rep. Wash.*, 41, 1025 and 297.

The rat and other small laboratory animals are able to synthesize vitamin PP and therefore do not require it in their diets, and the confusion was due to this fact, which was unknown at that time.

Chittenden and Underhill (1917) first produced experimentally in dogs a disease called black tongue, which is more or less of the same etiology as pellagra, but it was not until 1937 that Elvehjem [1] and his associate isolated nicotinic acid amide from liver and showed that it was curative for black tongue in dogs. (It is interesting to note that Funk when working on beriberi in 1911 isolated nicotinic acid from rice millings.)

The work on dogs was quickly followed by the treatment of pellagrins with nicotinic acid or its amide, and many of them responded dramatically, but in some cases thiamine, riboflavin or liver extracts were required in addition to the nicotinic acid before there was complete recovery.

Structure, Properties and Action of Nicotinic Acid. The empirical formula is $C_6H_5O_2N$, chemically it is pyridine-3-carboxylic acid, and the structure is :



Nicotinic acid occurs as white needle-like, nonhygroscopic crystals, stable in air and soluble in water. The melting-point of the crystals is 235–237° C.

As with some other vitamins it is a prosthetic group in one or more enzyme systems. It appears to act in the form of an amide combined with adenine, ribose and phosphoric acid to form an integral part of certain dehydrogenase systems.

Apart from the acid and its amide a number of substances related to nicotinic acid have been shown by Dorfman, Raman[2] and others to be physiologically active, but the activity of some of them is of a very low order. Among these are : ethyl nicotinate, nicotinic acid N-diethyl amide, β-picoline, nicotinuric acid and quinolinic acid.

[1] *J. Am. Chem. Soc.*, 59, 1767.

[2] *Ind. J. Med. Res.*, XXVII, 743.

Effects of Deficiency of Nicotinic Acid in Animals

Most animals and birds can synthesize this vitamin.

Black tongue in dogs has been long known to veterinary surgeons, it has also been inappropriately called canine typhus, and Stuttgart epizootic. When dogs are placed on diets such as wheat flour, peas and cotton-seed oil within one to six months they develop dark necrotic areas and gangrene of the tongue and buccal mucosa accompanied by bloody diarrhœa and soon followed by death. A similar disease has been shown to occur in swine.

Effects of Deficiency of Nicotinic Acid in Man

It is the main deficiency which gives rise to *pellagra*. This disease occurs in many parts of the world and is principally confined to the labouring classes. It followed the introduction of maize to Southern Europe, becoming prevalent as that cereal became a staple article of diet. At one time many thousands of cases were reported annually in the Southern States of America. The classical pellagra is almost as much associated with diets in which the staple cereal is maize as beriberi is associated with diets in which the staple cereal is highly milled rice.

The onset of the disease is slow, but once established it is characterized by a general atrophy of all the tissues of the body. The superficial layers of the skin become thin and a scaly dermatitis with very shallow ulceration occurs which is usually confined to surfaces of the body most exposed to the sun, namely, the face, back of the hands and front of the ankles. There is atrophy and thinning of the mucosa of the alimentary tract leading to sore mouth and intractable diarrhœa. Changes take place in the central and peripheral nervous system which result in dementia, and signs and symptoms of neuritis, but the latter is of a much milder degree than in the case of beriberi.

The three salient signs—dermatitis, diarrhœa and dementia—have been called the " three Ds " ; and a similar alliteration has been used to indicate the diets on which many pellagrins of the Southern States had existed—maize, molasses and meat (salt fat pork) have been called the " three Ms."

Many cases of pellagra reported from India[1] and elsewhere are

[1] Raman, T. K. (1940), *Ind. J. Med. Res.*, XXVII, 743.

not of the classical type, and the only sign common to them is dermatitis of various degrees on the exposed surfaces. They appear to be due to primary or conditioned malnutrition in which the deficiencies are various and many of the patients do not respond to the administration of nicotinic acid.

Treatment of Pellagra. The patient should be given by mouth 0·5 gm. of nicotinic acid daily in five doses of 0·1 gm. ; or 10–20 mg. doses in physiological saline injected parenterally four times daily.

The diet must be of high caloric value (3,500–4,000 calories), and as most patients have anorexia, every effort is necessary to wean them to such diets. The diet should contain one quart of milk, beef juices, liver and other foodstuffs rich in nicotinic acid, and must be given in small amounts at frequent intervals. Liver extracts, thiamine and riboflavin may be necessary parenterally, because of faulty absorption.

Pellagroid. There has been a tendency to refer to various types of malnutrition as pellagroid. This has been especially the case in reference to malnourished children who have skin changes, of which the two commonest are mosaic skin and crazy pavement skin (*vide* p. 153). Many of these cases in no way resemble the classical type of pellagra nor is there any evidence that the principal deficiency is nicotinic acid. It is far better to refer to these cases under the general term *malnutrition*, even the term polyavitominosis is not quite correct because most of these children have been fed on cereal gruels and show signs of protein and calcium deficiency.

Sprue. Nicholls [1] from studies in Ceylon, and Elders [2] in Java, had advocated for many years that sprue is a deficiency disease. The pathological changes in the visceral organs of those dead of sprue bear a resemblance to the changes in these organs in pellagrins. The general hypothesis is that sprue starts as an intestinal indigestion leading to faulty absorption and utilization of vitamins, and this produces conditioned deficiencies which cause still further degeneration of the digestive organs and thus a vicious circle is established. There may be various causes of the original intestinal indigestion, such as acute or chronic dysentery, or the use of unaccustomed and

[1] *Ind. Med. Gaz.*, LIII, Nov. 1918, and *Cey. J. Sci.*, III, 173.
[2] *Nederl. Tyschr. v. Geneesk* (1919), No. 21, 1683.

irritating diets, such as those heavily laced with condiments (curries); or possibly it may be due to specific infection of the intestine, but this is very improbable. Manson-Bahr [1] introduced the treatment of sprue with vitamins, and recorded that with doses up to 300 mg. of nicotinic acid and 3–9 mg. of riboflavin daily for three weeks definite cures or great improvement follows in almost all cases. Some patients need injections of liver extract to cure the anæmia (*vide* p. 45).

Laboratory Tests. Nicotinic acid is excreted in the urine mainly as trigonellin and to a smaller extent unchanged or as nicotinuric acid; trigonellin is not physiologically active. Methods have been elaborated for the determination of these derivatives in the urine. They are based on König's reaction in which the pyridine nucleus with cyanogen bromide and an aromatic amine yields a substance which can be estimated calorimetrically, but all methods are at present very complicated. Also account must be taken of the fact that trigonellin occurs in foodstuffs such as pulses and coffee. There is a marked reduction of trigonellin and nicotinuric acid in the urines of dogs with black tongue and human pellagrins compared with the amount in the urines of normal dogs and men.

Methods of Assay. Most of the analyses of foodstuffs for the content of nicotinic acid have been by chemical methods, such as the method of Dann and Hanaler.[2] But Waisman [3] and his associates have carried out many biological assays, using pariah dogs. Lwoff and Querido [4] have estimated nicotinic acid in blood serum by using *B. proteus* which require this vitamin for active growth. Snell and Wright [5] have elaborated microbiological method using a lactobacillus needing nicotinic acid for growth and acid production and the amount of the acid is determined.

Thoroughly reliable chemical tests for the determination of nicotinic acid in all kinds of foodstuffs have not yet been developed, and biological assays with dogs are not entirely satisfactory, hence tables giving the amount of nicotinic acid in various foodstuffs must be considered of a provisory nature.

[1] *Tr. Roy. Soc. Trop. M. and H.*, XXXIV, 347.
[2] *J. Biol. Chem.*, 140, 201.
[3] *J. Nut.*, 19, 485.
[4] *C.R. Soc. Biol.* (Paris), 130, 1580.
[5] *J. Biol. Chem.*, 139, 675.

Unit of Measurement

The amount of nicotinic acid in any material is always referred to in terms of milligrams.

Human Requirements

The amount of nicotinic acid in a well-balanced European or American diet of 2,500 calories is about 40 mg. This amount is undoubtedly a safe level for the daily intake of an adult ; but it is an impossibly high amount under the economic conditions in most tropical countries. The rice diets of the masses of Southern India do not lead to pellagra or any signs of nicotinic acid deficiency, and

TABLE XXXI [1]

	Mg. *per* 100	*Mg.* *per oz.*		*Mg.* *per* 100	*Mg.* *per oz.*
Cereals :					
Barley (pearled)	3·0	0·8	Oats	1·0	0·3
Bran and pollards	10–40	3–11	Ragi (*Eleusine*)	2·0	0·55
(Buckwheat)	4·0	1·1	Rice (parboiled)	3–4	1·0
Farina	1·0	0·3	,, (raw milled)	2·0	0·55
Flour (white)	1·0	0·3	,, millings	25	7·0
Maize	1·2	0·34	,, ,, (conc.)	140	40
Millets (Cholam and Sorghum)	1·5	0·4	Rye	1·3	0·37
			Wheat	4·5	1·2
Pulses :					
Beans (dry)	2·5	0·7	Peanut (*Arachis*)	13·0	3·7
Dhal (*Cicer*)	4·5	1·2	Peas, dried (*Pisum*)	1·0	0·3
Lentils (*Lens*)	3·0	0·8	Soya bean	4·5	1·2
Vegetables and Fruits :					
Banana	0·6	0·17	Leaves (spinach, etc.)	1·2	0·34
Brinjal (Egg plant)	0·8	0·22	Potatoes	1·5	0·40
Cabbage	0·3	0·08	Potatoes (sweet)	1·5	0·40
Cucumber	0·3	0·08	Tomatoes	0·3	0·08
Dates (dried)	2·0	0·55	Yams	1·0	0·3
Grass (dried)	7·0	2·00	Yeast	20–60	6–17
Animal Products :					
Cheese	0·2	0·06	Liver	10–40	3–12
Eggs	0·1	0·03	Meat (muscle)	3·5	0·8–1·4
Fish	2–4	1·00	Milk (cow's)	0·2	0·06
Heart	4–6	1–1·7	,, (human)	0·1	0·03
Kidney	4–10	1–3	Sweetbreads	4·0	1·1

[1] *Nut. Abs. and Rev.*, 10, 462 ; *J. Nut.*, 23, 417 ; *ibid.*, 24, 235.

where parboiled rice is the staple cereal there is about 20 mg. of this vitamin in a diet of 2,500 calories on the basis that parboiled rice contains 3 mg. per 100 gm. ; or where milled raw rice is the staple article these diets do not contain more than about 15 mg. in a diet of 2,500 calories on the basis of 2·2 mg. of nicotinic acid per 100 gm. Supposing the rice in these diets was replaced by maize, the other constituents remaining the same, then the diets would contain less than 10 mg. of nicotinic acid per 2,500 calories, and the prolonged use of them would probably lead to pellagra.

The American National Research Council Committee has estimated the nicotinic acid requirements of man as 15–20 mg. a day for 2,500 calories ; 20 mg. is certainly a safe amount.

The quantity of nicotinic acid in foodstuffs is given in Table XXXI.

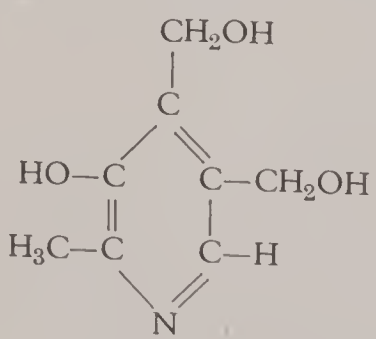
PYRIDOXINE

Synonyms : Vitamin B_6. Adermin.

This vitamin has been referred to by many terms during the years when vast numbers of animal experiments have been done in efforts to unravel the factors of vitamin B complex, and among these terms are : rat anti-pellagra factor, vitamin B_6, anti-acrodynia factor, factor 1 and factor γ.

This vitamin was first isolated in 1938 by Lepkovsky,[1] and Keresztesy and Stevens [2] working independently. It was synthesized by Harris and Folkers [3] in 1939, and named pyridoxine by György and Eckhart [4] (1939). The synthetic form is available on a commercial basis.

Chemical Composition. The formula is $C_8H_{11}NO_3$. Structurally it is 2-methyl-3-hydroxy-4 : 5-bihydroxymethyl pyridine.



[1] *Science*, 87, 169.
[2] *J. Amer. Chem. Soc.*, 60, 1267.
[3] *Science*, 89, 347.
[4] *Nature*, 144, 512.

Pyridoxine has a melting-point of 157° C. and can be purified by sublimation. Pyridoxine hydrochloride is the form commonly used, it is water soluble and has a melting-point of 295° C.

Effects of Deficiency of Pyridoxine in Animals

The vitamin was discovered because its deficiency results in the development of dermatitis in rats, which is not cured by nicotinic acid or riboflavin but clears up when an extract of yeast is given to the affected rats.. Pyridoxine in daily doses of 15γ will cure this dermatitis in rats, provided the animals also receive sufficient unsaturated fatty acids such as linoleic. Pyridoxine-deficient rats also show muscular atrophy, and epileptiform fits. Dogs on a diet deficient in pyridoxine develop anæmia which becomes very severe in 4–9 months, and later there are convulsions and cardiac embarrassment with accumulation of serous fluid in the chest; post-mortems show many changes, including chronic congestion of the liver and myelin degeneration of the peripheral nerves.

Pigs on pyridoxine-deficient diets show hypochromic anæmia and epileptiform fits.

Pyridoxine is associated with the proper utilization of fatty acids and may be the prosthetic group of the enzyme which brings about the phosphorylation needed for the absorption of fatty acids.

Pyridoxine Deficiency in Man

Very little is known concerning the effects of a deficiency of pyridoxine in man. A case [1] has been described of a patient who had pellagroid symptoms and a very sore smooth tongue with magenta-coloured edges, the condition of the tongue was refractory to nicotinic acid, thiamine, ascorbic acid and vitamin A, but cleared up rapidly when 100 mg. of pyridoxine hydrochloride was given daily intravenously.

Pyridoxine is reported to be of value in the treatment of the nervous signs and symptoms of pellagra. It has been reported to be of some value in the treatment of Sydenham's chorea in children (12–60 mg. daily). And it has been tried without much effect in the treatment of muscular dystrophies.

[1] *J.A.M.A.*, 117, 26, 2247.

Human Requirements

These are unknown, but judging from animal experiments and the fact that the carcase of a rat contains a little less than 1 mg. per 2,500 calories, it is probable that 1 mg. daily would amply meet all human requirements, and if this is so a deficiency is very unlikely to occur in human diets.

Effects of Storage and Cooking

Pyridoxine is very stable to heat, acids and alkalis, and the amounts in foods are unlikely to be affected by storage or cooking.

Methods of Assay. The biological method is by determining the growth response of depleted rats fed varying amounts of the foodstuffs being tested.

Scudi [1] and Swaminathan [2] have used chemical methods. The development of chemical methods may be of great value in testing for deficiency of this vitamin by blood and urine analysis.

The content of pyridoxine in foodstuffs is given in Table XXXII.

TABLE XXXII

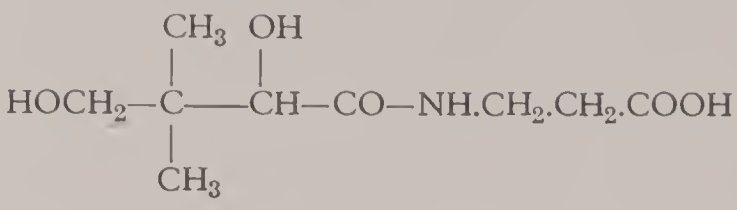
Cereals:	γ *per gm.*	*Pulses:*	γ *per gm.*		γ *per gm.*
Wheat	9	Dried gram, Dhals, Dried beans	8–10	Liver	14
White flour	4			Mutton	5
Raw unmilled rice	7			Milk	2
Raw highly milled rice	4	*Vegetables:*		Yeast	50
Maize	9	Beetroot	1	Rice millings	20
Millets	8–10	Carrots	3		
		Potato	2		
		Cabbage	2		

PANTOTHENIC ACID (Filtrate Factor)

A compound of β-alanine and a hydroxy fatty acid had been found by Williams [3] (1938) to be needed for the growth of yeast cells; he called this pantothenic acid. He forwarded a sample to Jukes [4] (1939), who found that it was identical with the filtrate factor needed to prevent dermatitis and other pathological conditions in the chicken and rat.

[1] *J. Biol. Chem.*, 139, 707.
[2] *Ind. J. Med. Res.*, 29, 561.
[3] *Abs. Div. Org. Chem. Amer. Soc. Milwaukee.*
[4] *J. Biol. Chem.*, 129, 225.

Chemical Constitution. Pantothenic acid has the percentage formula $C_9H_{17}O_5N$ and structurally is :



Pantothenic acid was first synthesized by Williams and Major [1] (1940).

Deficiency of Pantothenic Acid in Animals

Chickens develop dermatitis, the eyelids adhere and there is degeneration of the spinal cord.

Mice in the early stages of the deficiency lose hair, and later there is complete alopecia, serous exudate around the eyes, spinal curvature and death. Rats show irregular dermatitis with greying of the fur, adrenal necrosis and skin ulceration. The dog and pig have diarrhœa, anorexia and anæmia. And in the latter paralysis of the hindquarters occurs. The lipoids (cholesterol lipoid phosphorus) of the blood of dogs fall to half or less of the normal amount.

The effects of a deficiency of pantothenic acid in man is unknown, probably because almost any diet contains a sufficiency. Infants weaned on refined cereal gruels and showing signs of severe malnutrition appear to lose pigmentation of the hair and skin. Possibly pantothenic-acid deficiency plays a part.

Human Requirements

These are unknown but, judging from animal experiments, probably 5 mg. daily are sufficient. More is needed during growth than in later life. The young rat needs 100γ per day at the age of 3 weeks, but only 25γ per day is needed by a rat when 10 weeks old to prevent the appearance of characteristic lesins of a deficiency.[2]

Pantothenic Acid in Foodstuffs

The vitamin occurs in the free and combined state, and it can be set free by digestion.

[1] *Science*, 91, 246.

[2] *J. Nut.*, 23, 545.

This acid is required for the growth of certain bacteria, and a rough estimate of the amount of it in foodstuffs can be made by adding minute quantities of each foodstuff to a synthetic media lacking pantothenic acid, and the determination is made from the amount of growth of the bacteria as shown by turbidity. There is great variation in the amount of pantothenic acid in different samples of the same foodstuff. Table XXXIII gives the average results of microbiological assay by Jukes [1] and others.

TABLE XXXIII

Panthothenic Acid in γ per gm. Dry Material

Very good sources:	*γ per gm.*	*Moderate sources:*	*γ per gm.*
Brewer's yeast	200	Carrots	13
Liver	180	Oats	11
Eggs	108	Wheat	11
Pea meal	50	Rice	10
Whey	50	Barley	10
Sweet potatoes	40	Spinach	10
Beef	40	Onion	10
Milk	35	Maize	8
Good sources:		Orange	7
Salmon	28	Highly milled rice	4
Potatoes	28	Banana	4
Taro	28	*Very little:*	
Pumpkin	23	Coconut, turnips, prunes, raisins, beets and pineapples	
Tomatoes	20		
Split peas	20		
Cow peas	15		
Soya meal	15		

BIOTIN

Synonyms: Vitamin H. Co-Enzyme R.

The word bios was first used by Wilders [2] (1901) for substances necessary to promote the growth of yeast. It is now used to cover many growth-promoting factors of yeast, and biotin is among these factors. Boas [3] in 1924 found that when rats were fed on diets containing dried egg white they lost weight, developed blepharitis, dermatitis with loss of hair and gangrene of the tip of the tail, probably due to vasoconstriction. These changes did not occur when the egg white was boiled. At first it was thought that raw

[1] *J. Nut.*, 21, 193. [2] *Le Cellule*, 18, 313. [3] *Biochem. J.*, 18, 422.

egg white was toxic, but it was found that many foodstuffs contained some factor which prevented " egg white injury." György [1] (1939) called this factor vitamin H. It has been found that vitamin H and biotin are identical. The protein factor in egg white which combines with biotin and prevents its absorption from the intestine has been isolated, purified and called *avidin*. Another " substance " which is identical with biotin is " Co-enzyme R," needed for certain respiratory enzyme action by *Rhizobium trefolii*, a root nodule bacterium.

Chemical Composition. Kögl and Tonnis [2] first isolated biotin in 1936. Its composition is $C_{10}H_{16}O_3N_2S$. Du Vigneaud [3] showed that it is a bicyclic compound, and has a five-membered urea ring, a ring containing sulphur in thio-ether linkage and a fatty acid side-chain.

It is one of the most physiologically active substances known and will promote the growth of yeast in a dilution of 1 in 400 billion.

Effects of Deficiency in Animals

A deficiency in the diets of rats leads to the same clinical picture as occurs in " egg white injury," mentioned above. A deficiency in chicken leads to a scaly dermatitis.

Effects of Deficiency in Man

A deficiency of biotin is not possible in ordinary human dietaries ; but an interesting experiment has been carried out in America by Sydensticker [4] and four associates in the production of " egg white injury " in volunteers. The diet used was low in biotin, and included in it daily was 200 gm. of dehydrated egg white which was given in solution in a one-third aliquot with each meal. In about the 4th week a scaly dermatitis occurred and quickly disappeared to return later in the hands and feet of one of the volunteers. During the 7th and 8th weeks their skins had a strange greyish pallor out of proportion to the small degree of anæmia which had developed. The tongue became denuded in patches but remained

[1] *J. Biol. Chem.*, 131, 733.
[2] *Ztschr. f. physiol. chem.*, 242, 43.
[3] *Science*, 96, 455.
[4] *J.A.M.A.* (1942), 118, 1199.

pale and was very different from the ruddy erosion seen in pellagra and ariboflavinosis. Mild depression during the early weeks progressed to extreme lassitude and somnolence, one volunteer had hallucinations and two others mild panic states. All had muscle pains and hyperæsthesia; and anorexia progressed to nausea and sitophobia. Precordial pain and other evidence indicated coronary ischemia in two of the devoted victims. The daily excretion of biotin fell to 4–7γ from a normal of between 30 and 60γ.

The minimum amount of biotin needed to bring about prompt relief of all symptoms was 150γ injected parenterally.

Biotin in Foodstuffs

This vitamin occurs in two forms—free and bound. The latter can be freed slowly by digestion or by autoclaving the foodstuff for one hour with $2N.H_2SO_4$.

Lampen[1] and his co-workers have estimated the amount of biotin (free and bound) in various foodstuffs by a microbiological method, using a strain of the bacterium *Clostridium butylicum* which needs biotin for its growth. Table XXXIV gives their results.

TABLE XXXIV

Biotin in Foodstuffs

	γ per gm. dry matter			γ per gm. dry matter	
	Water extract	$2N.H_2SO_4$ *extract*		*Water extract*	$2N.H_2SO_4$ *extract*
Beef kidney	120	2,500	Soya bean	100	500
Pork liver	33	2,000	Spinach	450	480
Pancreas	670	1,220	Raspberry	590	460
Egg yolk	1,000	870	Walnut	140	380
Egg white	530	480	Carrots	400	285
Beef liver	20	130	Rice millings	170	270
Pork	35	60	Maize	100	80
Milk	35	35	Wheat	100	80
Cheese	26	24	Orange	100	80
Oats	80	240	Beans	30	64
String beans	200	230	Rye	23	57
Barley	180	200	Cabbage	62	32
Peanut	100	200	Potato	17	17
Banana	182	105			
Peas	95	110	(Alfalfa	260	280)
Tomato	1,000	400	(Cow manure	1,700	1,250)

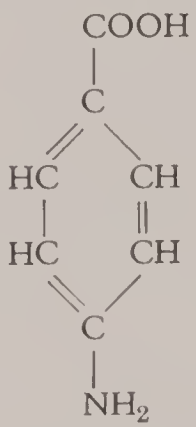
[1] *J. Nut.*, 23, 11.

It will be seen that many foodstuffs of animal origin which are rich in biotin have most of it in the bound form, this also applies to yeasts and a few vegetable foodstuffs. In a few cases the method of extraction with sulphuric acid destroys some of the biotin.

PARA-AMINOBENZOIC ACID

This substance was first recognized from its effect on bacterial growth. But there are now indications that it may have vitamin action in animals.

Para-aminobenzoic acid is a simple derivative of benzoic acid :



Ansbacher [1] reported in 1941 that *p*-aminobenzoic acid deficiency produced greying of the hair in rats curable by the administration of 3 mg. of this substance daily.

Sure found that a diet on which young rats grew well would not support reproduction or lactation. Tentatively calling the deficient factor B*x* he found that the inclusion of *p*-aminobenzoic acid and inositol in the diet changed a 95 per cent. failure of lactation to a 91 per cent. success. Therefore it appears that B*x* is a combination of these substances.

[1] *Science*, 93, 164.

CHAPTER VII

VITAMINS (*contd.*)

VITAMIN C

Synonyms: Ascorbic Acid. Cevitamic Acid.

In 1933, when the nature of vitamin C was discovered, Haworth and Szent-Györgyi [1] suggested the name "ascorbic acid."

The Committee of the American Medical Association, objecting to names connoting definite therapeutic utility, introduced the name "Cevitamic Acid."

Structure and Synthesis. Although Holst and Frolich [2] had produced experimental scurvy in guinea-pigs in 1907, and much work followed, yet very little progress was made for many years towards the isolation of this vitamin.

In 1927 Zilva [3] found that foods of high anti-scorbitic value had considerable reducing power as determined by the indo-phenol indicator. Somewhat later Tillmans and Hoish [4] used this indicator to distinguish fresh lemon juice from stale juice which had lost much of its anti-scorbutic potency.

They suggested that vitamin C might be related to a reducing hexuronic acid, which had been isolated by Szent-Györgyi from adrenal cortex, oranges and cabbage. In 1932 Szent-Györgyi [5] in Europe and Waugh and King [6] in America definitely found that the reducing hexuronic acid was vitamin C.

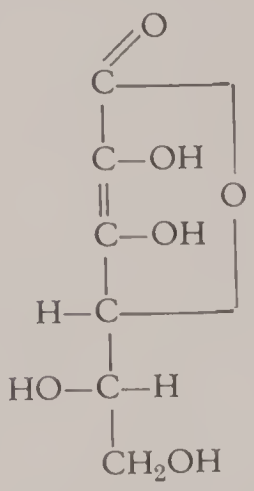
The formula for this acid is $C_6H_8O_6$.

Several methods for its synthesis have been published. It can be synthesized commercially at low cost by the catalytic or electrolytic reduction of *d*-glucose to sorbitol, and this is converted to *l*-sorbose then to sorburonic acid and finally *l*-ascorbic acid.

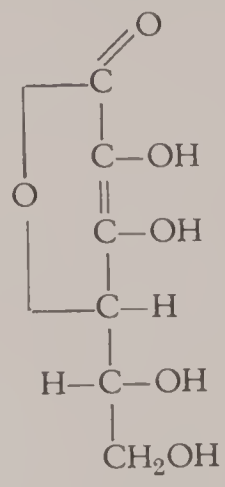
$C_6H_8O_6$ has been synthesized in many isomeric forms; *l*-ascorbic acid is the most active physiologically, others have a

[1] *Nature*, 131, 23.
[2] *J. Hyg. Camb.*, 7, 634.
[3] *Biochem. J.*, 21, 689.
[4] *Z. Unters. Lebensm.*, 63, 1.
[5] *Biochem. J.*, 26, 865.
[6] *Science*, 73, 630.

little activity, and some, such as *d*-ascorbic acid, are inactive, the following are structural formulæ of *l*-ascorbic and *d*-ascorbic acids :



Active *l*-ascorbic acid



Inactive *d*-ascorbic acid

Properties. When the vitamin is protected from oxidation it can be crystallized from water, alcohol and other solvents. The colourless crystals may form dense radiating clusters or plates or needles, depending on the solvent and rate of crystallization.

Action of l-ascorbic Acid. The vitamin plays a great part in the oxidative processes which occur in tissue respiration, and is one of the partners in the balanced chemistry of oxidation and reduction in the cells of the body. It probably enters into many enzyme systems.

The pathological changes which follow a deficiency of this vitamin are due to faulty production or maintenance of intercellular substances. The dentine of teeth and the matrix of bone is improperly and erratically laid down. The endothelial cells of the capillaries need the vitamin for the solidification of the intercellular substances to bind them firmly together, it is an increased fluidity which causes the fragility and hæmorrhages of scurvy.

Scurvy in Animals. Cattle, horses, dogs, cats and other mammals, and many other creatures such as birds, cannot be affected by a deficiency because they are able to synthesize the vitamin within their bodies. The only animals, besides man, in which scurvy has been known to have occurred are guinea-pigs and monkeys. When guinea-pigs are fed on cereal meals and water only they develop a severe scurvy and die in 20–40 days.

Tenderness and swelling of the joints, the gums and the jaws are the first symptoms, and the animal lies down and takes up postures to relieve as much as possible all weight on the tender limbs. The teeth become loose and the animal is unable to eat solid food. Hæmorrhages may occur in any part of the body and an hæmorrhagic diarrhœa is quickly followed by death. Post-mortem examination reveals hæmorrhages in various parts of the body; the teeth are easily extracted; the bones are rarefied and readily fracture; and there are enlargements at the costochrondral junctions.

Monkeys on a diet of boiled rice, wheat germ and autoclaved milk show signs of scurvy in 8–10 weeks. There is sponginess and bleeding from the gums and the teeth become loose. There may be hæmorrhages under the periosteum, into the orbit or almost any part of the body. The hind limbs become powerless, due to bleeding into the knee and hip joints. The bones become fragile.

Scurvy in Man. The disease is always slow in onset. There is weakness and lassitude. The earliest sign is bleeding from the gums following small injury. A follicular keratosis has been described as an early sign. As the disease progresses swelling of the gums increases, especially around the stumps of decayed teeth, the hypertrophy may be such that the teeth are almost buried in a mass of bluish, soft, fungoid tissue. Foul breath may be extreme. Sometimes numerous petechial hæmorrhages of the skin are an early sign, they produce a flea-bitten appearance; these small hæmorrhages are difficult or even impossible to see on the pigmented skin of most tropical races.

As the disease advances the tendency to hæmorrhage increases. There may be bleeding from the nose, lungs, bladder or bowels. Subcutaneous or intramuscular hæmorrhages give rise to brawny tender swellings of the limbs. There is usually some degree of anæmia. Pyrexia occurs in most marked cases of scurvy, probably due to oral sepsis or resorption of extravasated blood. There is a tendency to bronchitic and pneumonic infections.

Under tropical conditions the diagnosis of scurvy must usually be made by a scrutiny of the past diets of the patients and the condition of their gums.

Infantile Scurvy (Barlow's Disease). Some outbreaks of scurvy in

the sailing ships of old may have been mainly the result of a single deficiency. But this is not the case with infantile scurvy, such as occurs in children weaned on boiled milk, tinned foods or cereal gruels, because there are varying degrees of other deficiencies. It is not surprising, therefore, that authors are not in agreement on many of the less marked signs and symptoms or on the diagnosis in mild cases. The swollen spongy gums are stated by some authors to be less common in infants with scurvy than is the case in adults. Petechial hæmorrhages of the skin are uncommon. Signs and symptoms such as irritability, pain and tenderness of the limbs, pallor of those with white skins, or ashiness of those with dark skins, slight œdema, anæmia, liability to septic infections and fever, which are mentioned in description of infantile scurvy, are not diagnostic because they occur as the result of dietary deficiencies other than that of ascorbic acid.

In those cases where the known deficiency in the infant's diet has been followed by swollen and bleeding gums, painful swellings around the epiphyses of the bones, brawny hæmorrhagic swellings of the limbs, and hæmaturia or other bleeding, the diagnosis will not be in doubt. But in all other cases, or where sub-clinical deficiency is suspected, the diagnosis should be supported by tests for capillary fragility or chemical tests for the amount of ascorbic acid excreted in the urine.

Capillary Fragility. There are two methods of testing for this—one is by producing negative pressure on a small area of skin by means of a small cup and vacuum pump and the other is by positive pressure produced by a tourniquet or armlet of a sphygmomanometer (*vide* Appendix III, p. 334). These tests have considerable limitations, firstly they are not specific, a deficiency of citrin (vitamin P) (p. 147), and even anæmia, may give positive results, and secondly it may be difficult to see the small petechial hæmorrhages or ecchymoses of positive reactions in dark skins.

Chemical Tests. The amount of ascorbic acid excreted in the urine can be determined by titration with 2, 6-dichloro-phenolindophenol (*vide* Appendix IV, p. 335). The quantity of ascorbic acid excreted in the urine varies more or less with the amount taken in with the food. Some persons, however, destroy or use more of

the vitamin in their alimentary tracts or body tissues than others. When the diet has been rich in vitamin C the tissues of the body are "saturated," that is, they contain more or less as much of the vitamin as they are capable of storing, and consequently most of the vitamin taken in with the food is passed out with the urine. But in scurvy, even when sub-clinical, the body is not saturated, and very little ascorbic acid appears in the urine. In their early work Harris [1] and his associates recorded that when 700 mg. of ascorbic acid is given to a person who has been on a diet deficient in the vitamin it is not followed by a high excretion in the next twenty-four hours because most of it is taken up by the unsaturated tissues.

Table XXV (from Harris and Roy) gives examples in the case of infants :

TABLE XXXV

No.	*Age of child*	*Dose of vitamin C given, mg.*	*Vitamin C excreted in the following 24 hours, mg.*
1	7 months	100	0·7
2	11 ,,	100	0·3
3	9 ,,	100	10·9
4	13 ,,	100	5·0

The infants numbered 1 and 2 in Table XXXV had been on diets deficient in ascorbic acid, whereas the infants numbered 3 and 4 had been receiving sufficient.

The determination of vitamin C deficiency by giving test doses and later examining the urine is not as simple as might at first appear. These are variables, such as the amounts destroyed in the intestine or excreted in the fæces vary greatly, one diet having a greater oxidizing effort on the vitamin than another. Test doses ranging for adults from repeated doses of 100 mg. to a single dose of 1,000 mg. have been recommended. There has been discussion as to the percentage of the vitamin of the test dose and in the food which should appear in health in the urine twenty-four hours after it has been taken. Van Eekelen [2] recommends that the test dose should be injected subcutaneously, and this certainly should be done in cases of disorder of the alimentary tract.

Messerli [3] studied the excretion of ascorbic acid by many

[1] *Lancet* (1936), 1, 1488. [2] *J. Clin. Investigation*, 17, 393.
[3] League of Nations' *Bulletin of Health Organization*, X, 76.

thousands of the school children of Lausanne and found that the amount varied with the feeding and social status of the children, the average was between 1·4 and 1·5 mg. per 100 c.c. of urine; whereas 250 urines from adults gave an average of 1·55 mg. Messerli came to the following conclusion: "In saturation tests, in cases of vitamin balance ingestion of ascorbic acid is followed very quickly—within from half an hour to two hours—by a marked increase of excretion of this vitamin in the urine; this increase is not observed in cases of vitamin insufficiency. For this purpose the urine should be titrated three or four times, every half-hour after the ingestion of 0·05 gm. of ascorbic acid. A rise in vitamin excretion would signify vitamin sufficiency; the absence of rise, vitamin insufficiency" (*vide* Appendix IV, p. 335).

Treatment consists in giving adequate amounts of fruits or vegetables rich in vitamin C; or giving ascorbic acid by mouth or parenterally.

In countries where fresh foods are not always available, a fair amount of vitamin C may be obtained from sprouted grain. When dry grain is soaked in water in a porous vessel, or on wet sacking, it quickly germinates in warm climates and sprouts appear in twenty-four hours. Dry grain, which is almost devoid of this vitamin, produce it rapidly during germination. Hay and Roy give the following figures:

Dry pea	0 mg. per 100 gm.
,, ,, sprouted 1 day .	8 ,, ,, ,, ,,
,, ,, ,, 2 days .	69 ,, ,, ,, ,,
,, ,, ,, 3 ,, .	86 ,, ,, ,, ,,

Ahmad gives somewhat smaller amounts for various grams and beans: 2–3 mg. per 100 gm. for dry grain, and 7–25 mg. per 100 gm. for the sprouted grain.

All grains produce vitamin C when germinating, and this includes cereals, pulses and other edible seeds. It is not necessary to consume the whole of the sprouting grains, most of the ascorbic acid is in the sprouts, and these can be removed from the grain for consumption.

Methods of Assay. The original methods consisted of feeding guinea-pigs on a mixture of scurvy-producing foodstuffs such as

bran, crushed oats and dried skimmed milk, and determining the minimum amount of the foodstuff being assayed which would prevent the onset of scurvy. Many guinea-pigs are required for these assays, the errors are considerable and three months are needed for each estimation.

Hozer [1] in 1926 introduced a method of biological assay which, as modified by Key and Elphick [2] and others, became the preferred method. The method is founded on the changes which take place in the teeth of scorbutic guinea-pigs. (For details the reader should consult Coward's Biological Standardization of Vitamins.)

The quantity of vitamin C in foodstuffs is now generally determined by chemical methods, usually by titration with indophenol, but in some cases it is necessary to check the results by bioassay.

Units of Vitamin C

The original "International Unit" was 0·1 ml. of lemon juice, and about 10 units daily are necessary to protect guinea-pigs from developing naked eye lesions of scurvy. Most samples of lemon juice contain about 0·05 mg. of *l*-ascorbic acid in 0·1 ml., and hence this amount has become the "New International Unit." But such a unit is not necessary now that ascorbic acid is available in pure form, and the vitamin potency of foodstuffs should be referred to in terms of milligrams.

Human Requirements

These cannot be closely correlated with sex, age or body weight. The American National Research Council Committee recommended that the daily consumption of an adult should be 75 mg. The American army daily ration contains 70 mg., and in one experiment an additional dose of the vitamin did not improve the physical performance or the well-being of the troops. Therefore 70 mg. is ample for a young man leading a strenuous life, and is considerably more than is needed by the average individual. There is one group of persons, namely, surgical patients who should always receive ample vitamin C, or there may be delayed healing of wounds or setting of bones.

[1] *Brit. J. Exp. Path.*, 7, 356.

[2] *Biochem. J.*, 25, 888.

The following amounts will meet the daily requirements :

Children under 12 years of age . .	35 mg.
Persons over 12 years of age . .	40
Pregnant and nursing mothers . .	50
Surgical patients	60

Effect of Storage, Cooking and Preparation of Foodstuffs

Ascorbic acid is very easily oxidized and this is enhanced by high temperatures, light, drying and an alkaline medium. It follows that much vitamin is lost during storage and cooking. Dry grains of cereals and pulses, dried milk, salted and canned meats and fish are nearly devoid of anti-scorbutic properties. Vegetables and fruits, however, can be preserved in tins without a great loss of ascorbic acid, but there are two necessities—firstly the medium in which they are being prepared must be acid, and secondly air must be excluded as far as possible during the sterilization process. For instance, tomato juice with a natural acidity of pH_4 may be boiled for an hour with a destruction of less than 50 per cent. of the content of ascorbic acid. Indeed, most samples of canned tomatoes on the market contain a considerable amount of the original vitamin C.

Much vitamin C may be lost when vegetables or fruits are prepared for cooking and the following points should be noted :

(*a*) Crushing, finely shredding or mincing causes a loss in foodstuffs because either oxidative enzymes are set free or air becomes intimately mixed with the food. When cabbages or other leaves are shredded the oxidative enzymes destroy much of the ascorbic acid ; but when boiled potatoes are mashed the destruction is due to the direct action of the oxygen of the air. G. N. Jenkins[1] gives the following results when potatoes are boiled and mashed.

	Kept hot during	*Ascorbic acid, mg. per 100 gm.*
Boiled potatoes . .	0 minutes	5·4
,, ,, . .	20 ,,	4·0
,, ,, . .	60 ,,	2·5
Boiled then mashed .	0 ,,	5·0
,, ,, ,, .	20 ,,	1·8
,, ,, ,, .	30 ,,	0·5

[1] *Nature*, 151, 473.

(*b*) Long soaking or cooking in water leaches some of the ascorbic acid from vegetables.

(*c*) Foodstuffs with large surfaces in proportion to their weight, such as leaves, are more easily oxidized than foodstuffs with relatively small surfaces, such as potatoes, in which air cannot reach the interior.

(*d*) Soda should not be used when cooking vegetables.

Ascorbic Acid in Foodstuffs

Table XXXVI gives the ascorbic acid content of many foodstuffs (see also Tables LII *et seq.*, pp. 186 *et seq.*).

It will be noticed that many of the best sources are fruits and vegetable leaves which are apt to be despised because they are not very palatable, and some of the most palatable are poor sources.

TABLE XXXVI

Average Amount of Ascorbic Acid in Foodstuffs

	mg. per 100 *gm.*	*mg. per oz.*		*mg. per* 100 *gm.*	*mg. per oz.*
Very rich sources:					
Unripe walnuts (pickled)	1,000	285	Lotus leaves	150	40
Indian gooseberry (*nelli*)	700	200	Guava fruit	150	40
Cashew fruit	600	170	Chillies	150	40
Rose hips	500	140	Ipomœa leaves	100	28
Black currants	300	85	Drumsticks	100	28
Mulberry leaves	200	55	Spinach	100	28
Fairly rich sources:					
Pine needles	70	20	Snake gourd	30	9
Mustard leaves	70	20	Ridge gourd	30	9
Cabbages and other leaves	50	14	Green peas	25	7
Hog plums (*Spondias*)	50	14	String beans	25	7
Papaw	50	14	Gooseberry, Custard apple, Beetroot, Garlic, Potato, Sweet potato, Granadilla	20	6
Strawberry	50	14			
Sprouted grain	50	14			
Citrus fruits					
Orange	50	14			
Lemon	50	14			
Lime	50	14			
Mango	40	11	Liver	20	6
Bitter gourd	30	9	Fish roes	15	4

TABLE XXXVI (*contd.*)

Average Amount of Ascorbic Acid in Foodstuffs (*contd.*)

Poor sources:	*mg. per* 100 *gm.*	*mg per oz.*
Kidney	10	3
Ladies fingers	8	2
Melon	7	2
Coconut	5	1
Apples, Bananas, Bread, Bread fruit, Cereals (dry), Cucumber	2–5	1

	mg. per 100 *gm.*	*mg. per oz.*
Fish (fresh), Grapes, Jak fruit, Meats (beef, etc.), Milk, Peaches, Pears, Pumpkins, Pulses (dry)	2–5	1

VITAMIN D

(Calciferol) (Viosterol)

The clinical evidence that rickets was due to a dietary deficiency did not bring conviction, and it was not until between 1919 and 1921, when Mellanby,[1] experimenting with puppies, showed that the disease was definitely of dietary origin, and he thought that the antirachitic factor was probably vitamin A.

But it was shown in America that certain foods which were rich in vitamin A would prevent rickets and further that Hopkins' method of destroying vitamin A by blowing hot air through cod-liver oil did not affect the antirachitic property of the oil. For these and other reasons a second fat soluble vitamin was postulated in 1922 and called vitamin D.

As long ago as 1890 Dr. T. A. Palm [2] had pointed out that the geographical distribution of rickets suggested that it was in some way prevented by sunlight and advocated the exposure of rickety children to the sun. When the first World War brought many deprivations to the people of Europe, rickets became rife and the Jewish physician, Huldschinsky, in 1919 tried the experiment of exposing the affected children, not to sunlight, but to the ultra-violet rays of the mercury vapour lamp, and the children were cured. Dr. Harriette Chick and her colleagues, working in war-

[1] *Lancet*, 1919, 1, 407, and *Sp. Rep. Ser. Med. Res. Counc.* (Lond.), No. 61.

[2] *Practitioner*, 45, 271.

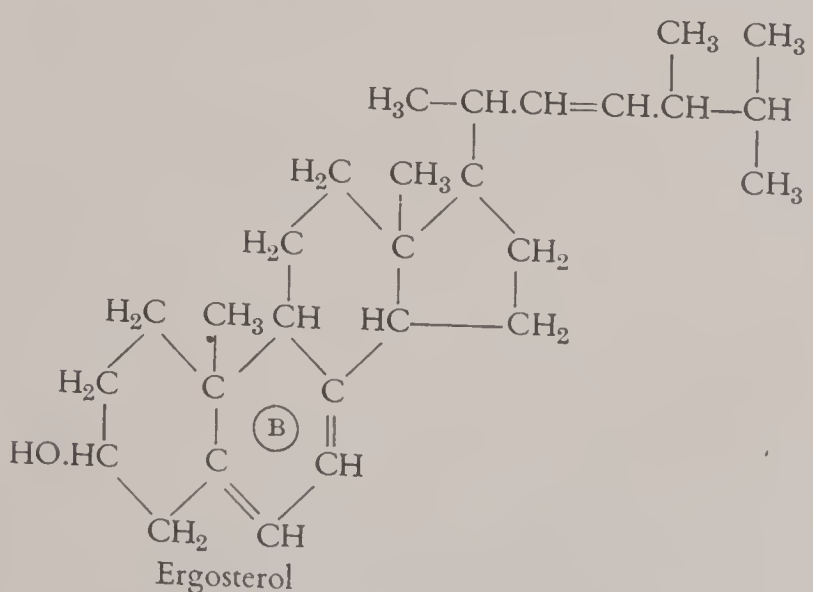
ruined Vienna, had similar successes. The next development came when it was shown that certain foods which are inactive become actively antirachitic after irradiation with ultra-violet light.

The biochemists of Europe and America were slowly coming to the conclusion that vitamin D belonged to that group of fat soluble substances called sterols. It was found that when inactive commercial preparations of cholesterol were irradiated they became highly antirachitic, but very pure preparations of cholesterol were valueless for this purpose : therefore it appeared probable that some other sterol present as an impurity was the provitamin. This led biochemists to irradiate and test various sterols for curative properties on rachitic rats.

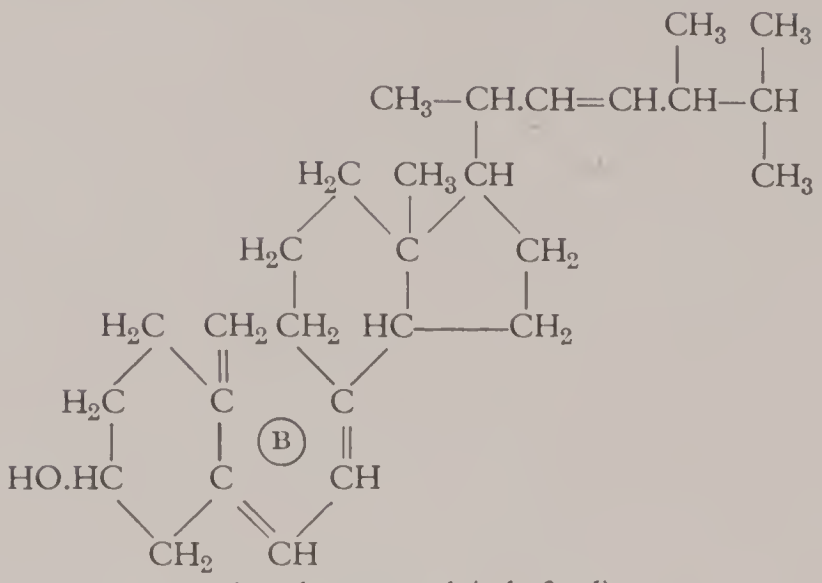
Many years ago a sterol was isolated from ergot—the fungus of rye—and called ergosterol ; and it was found independently by Bourdillon and his team in London and Windaus and his team in Germany that irradiated ergosterol is potently antirachitic. The chemistry, however, is far from simple.

Chemistry of Vitamin D. Egosterol and one form of the active vitamin have the same formula $C_{28}H_{44}O$. Many isomers may have this formula, and irradiated ergosterol consists of a mixture of these. It was not until 1932 that the London and German teams mentioned above isolated pure vitamin D from this mixture. The London workers gave the name *calciferol* to this crystalline synthetic vitamin D.

The structure of ergosterol and calciferol are as follows :



Ergosterol



Irradiated ergosterol (calciferol)

It will be seen from the above structural formulæ that ergosterol has three double bonds and that on irradiation calciferol is formed by the opening of the ring marked B and the appearance of a fourth double bond.

At one time it was believed that calciferol was the only form of vitamin D, but doubt arose when it was found that irradiated ergosterol was far less potent as a calcifying agent for the chicken than its equivalent in cod-liver oil on a rat assay basis. This discovery was followed by the semi-synthesis of 7-dehydrocholesterol, which on irradiation was found to become actively antirachitic and to be a more potent calcifying agent for the chicken than calciferol. It has been shown that 7-dehydrocholesterol and not ergosterol is the provitamin of commercial cholesterol and that it is the principal form of vitamin D in butter and fish oils, and also it is the provitamin in the skin of man and animals which sunlight changes into the active vitamin. Another sterol, 22-dihydroergosterol, on irradiation becomes antirachitic though not quite so potently as the two sterols already mentioned, but it is of the greatest interest to us because it occurs among the phytosterols of the plant kingdom and may be found to be important in the more or less vegetarian diets of the labouring classes of many tropical countries.

As already stated, irradiated ergosterol consists of a mixture of isomers and at no time during irradiation does any particular isomer

preponderate, and if irradiation is carried out too strongly, or too long, poisonous products occur in the mixture.

The following are the four important forms of vitamin D :

(1) Vitamin D_1 was the name given to *irradiated ergosterol* and therefore is a mixture of isomers.

(2) Vitamin D_2 is calciferol and when dissolved in oil is called *viosterol.*

(3) Vitamin D_3 is irradiated 7-dihydrocholesterol.

(4) Vitamin D_4 is irradiated 22-dihydrocholesterol.

Apart from these, six or more other sterols have been shown to have antirachitic properties, but they are of lower potency.

Action of Vitamin D. It is indirectly concerned with the formation of hard healthy bones and teeth and has been called the antirachitic vitamin.

The present view of the action of vitamin D is that it does not act directly on the bone cells to promote calcification, but that it promotes absorption of calcium and phosphorus from the alimentary tract and maintains a concentration of these minerals in the blood within normal limits unless it is taken in excess. How it does this is not understood. The following points are stated in support of the above view.

(1) In rachitic children and animals the amounts of calcium and phosphorus in the blood are below normal ; and when excess of vitamin D is given these minerals are increased in the blood above normal. Table XXVII illustrates this :

TABLE XXXVII
(After Eddy and Dalldorf)

	Mg. P in 100 c.c. blood	*Mg. Ca in 100 c.c. blood*
Rachitic (no vitamin D)	3	7
Normal (with vitamin D)	4–5	10
Hypervitaminosis (excess vitamin D)	8	15

(2) Analysis of the fæces of rachitic children and animals shows that 90–100 per cent. of the calcium and 60–70 per cent. of the phosphorus of the diets is being excreted, whereas when the amount of vitamin D in the food is satisfactory the percentage of these minerals passed in the fæces is much less.

(3) A bone removed from a rachitic animal and placed in normal serum will take up and deposit calcium and phosphate salts ; and it will even do this in aqueous solutions but only if the minerals are in the correct proportions. Vitamin D is not necessary for this action.

The enzyme phosphatase is present in growing bone and plays a part in calcification in that it releases inorganic diffusible phosphates from organic phosphates. In rachitic subjects this enzyme passes in greater quantity than normal from the bones to the blood and sets free inorganic phosphates.

The function of vitamin D to maintain proper amounts of phosphorus and calcium in the blood is necessary for good health at all periods of life because calcium has many parts to play, such as the regulation of the heart rhythm, the control of muscle and nerve excitability, the coagulation of the blood to protect against hæmorrhage, the excretion of urine and the control of membrane permeability.

Bile salts are necessary for the proper absorption of vitamin D from the intestine.

Rickets in Animals. The disease has always been common in domesticated dogs (Pl. V, Fig. 9). The reason is that dogs in their wild state, as with all other carnivorous animals, obtain ample quantities of minerals and vitamin D from the bones and bodies of the creatures on which they feed. Man has weaned the dog to an omnivorous diet, but its constitution has not become as physiologically adapted to this diet as is the case with some rodents which in the wild state are omnivorous.

Rickets can be produced in rats and rabbits only under strict laboratory conditions, their bodies can make shift with very small amounts of vitamin D provided they are receiving ample minerals, and the ratio of calcium to phosphorus is in the neighbourhood of unity. In most of the studies of rickets in rats the animals have been fed on diets with a ratio of Ca : P of 4 : 1 or even higher, and the type of rickets produced may be called *low phosphorus* rickets.

In rickets in animals there is a varying mixture of rachitic and osteoporotic changes ; the former term refers to the changes at the growing end of the bones where there is enlargement and softening

PLATE V

FIG. 9.

RICKETS (AFTER MELLANBY)

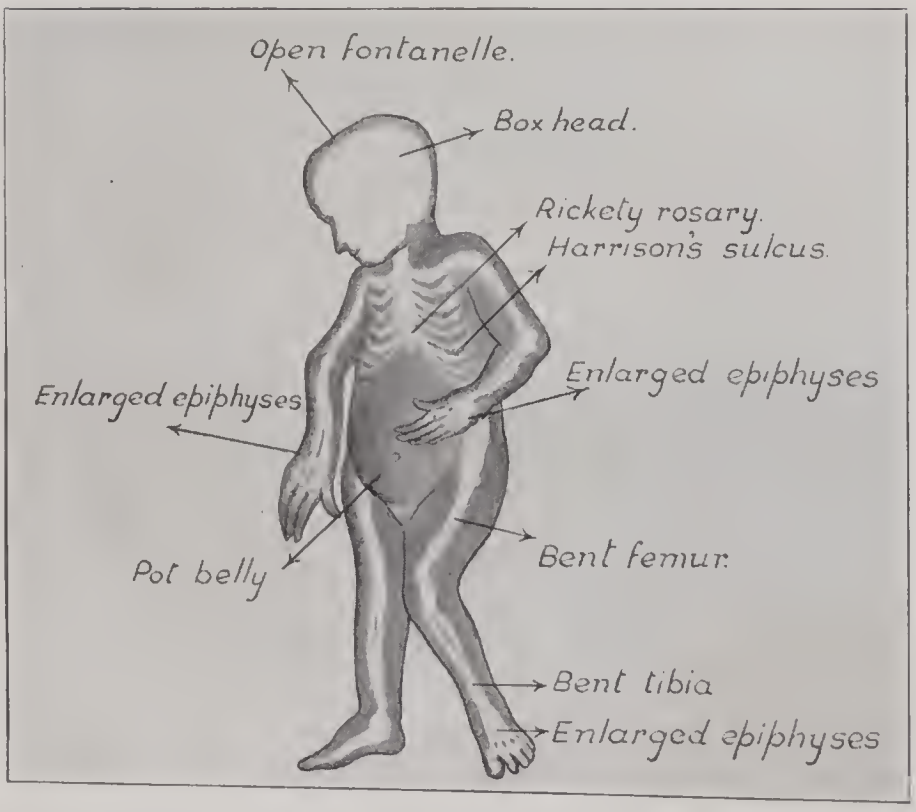


FIG. 10.

BONE CHANGES IN RICKETS

[*To face page* 134

from the laying down of much uncalcified osteoid tissue, and the latter term refers to absorption of minerals from bone already laid down and leading to loss of weight, rarefaction and fragility of the bone.

Deficiency of Vitamin D in Man

Rickets in children and osteomalacia in adults are two general bone diseases associated with vitamin D shortage. The latter disease occurs principally in pregnant or lactating women, whose bodies must supply the needs of their children. In both diseases the ash which normally constitutes about 60 per cent. of bones is reduced, sometimes to as low as 30 per cent. or even less.

The common changes in the skeleton of rachitic children are (Pl. V, Fig. 10) :

Skull : Protruding forehead with cruciform depressions along the sutures, the child has a " box-headed " appearance and the anterior fontanelle remains widely open after the normal period of closure at the 18th month.

Chest : A line of enlargement at the costochondral junction of the ribs gives rise to what is called the " rickety rosary." The softened ribs cave in from muscular action and cause " pigeon chest " with broad grooves running antero-laterally on either side of the chest (Harrison's sulcus).

Limbs : There are irregular enlargements at the epiphyses which may be especially marked at the wrists or ankles ; the femur curves forwards and outwards ; and bending of the tibia may cause bow legs or knock knees, according to the directions of the bending.

Spine : Kyphosis occurs from curvature of the vertebral column.

Eruption of the teeth is delayed in rachitic children. (For ages at which the teeth normally erupt see Appendix V, p. 336.)

A child may be receiving insufficient vitamin D for several months before the changes slowly taking place in the bones can be revealed by inspection or palpation. A diagnosis of incipient rickets may be based on X-ray photos of the wrist where the earliest changes show cupped and ragged metaphysial margins with lack of normal density of the shaft of the bones.

Hypoplasia and Decay of the Teeth. There are many advocates that vitamin D deficiency is a frequent cause of these among the children of the temperate climates. But these changes in the teeth are prevalent among the labouring-class children in the tropics, who show no signs of rickets and spend much time in the sun, and the fault is far more likely to be due to mineral and other deficiencies (such as vitamin A).

The most serious effect of osteomalacia in women is due to the weight of the body and muscular action distorting the pelvis and narrowing the transverse dimensions of the pelvic opening, so that it becomes impossible for a woman to give natural birth to a child.

Rickets and Osteomalacia in the Tropics. It has already been stated that these diseases are far more common in temperate climates than in the tropics. Some of this, however, is more apparent than real in respect of infants, because infantile mortality is very high in hot climates, and an ailing child usually dies of general malnutrition or an intercurrent infection long before marked signs of rickets can develop. Minor degrees of "rickety rosary" and enlargement at the epiphyses may be found at post-mortem in the bones of many infants who have died of malnutrition. As the infants of the labouring classes learn to walk and get about in the sun any minor defects from vitamin D shortage quickly disappear.

Rickets appears among older children in the tropics when a sufficiency of sunlight fails to reach them. This occurs in the slums of such large towns as Bombay and Calcutta, where the needed sunlight cannot reach the interior of the dark dwellings and falls upon the narrow streets only for a short time each day. Other cases occur among poor-class children who have been confined for a long time to bed because of some chronic illness or injury.

Although there is a free supply of vitamin D from sunlight available for all living in the tropics, yet in some countries there are people who are so swayed by ignorant prejudices or caste lore, that they guard their women (and in some cases their children) from the health-giving rays of the sun. Osteomalacia occurs among the middle-class women who practice purdah and are never allowed to leave the confines of dark dwellings and cannot afford the expensive animal products which contain vitamin D. The

practice of purdah occurs among the better class Mohammedans of Egypt, India and elsewhere; but the exigencies of life in the tropics deny the labouring classes the extreme forms of this unhealthy practice.

Standard of Measurement

The International Unit is that amount of vitamin D in 1 mg. of a solution of ergosterol irradiated under defined conditions. This is equal to 0·025γ of crystalline calciferol. The unit of the United States Pharmacopœia is differently defined, but it is equivalent to the International Unit.

Human Requirement

Three hundred international units (7·5γ) of vitamin D daily as found in fish-liver oils will effectively protect an infant or child from rickets. Much larger amounts are required to cure the disease, and at least 4,000 units should be given daily.

There are vast numbers of children of the labouring classes in the tropics who receive little, if any, vitamin D in animal foodstuffs and yet become adults without ever showing signs of rickets. Their supply of this vitamin comes entirely from the sunlight, partly through the irradiation of their skins and probably to a smaller extent from the irradiation of their foodstuffs.

The ultra-violet rays of the sun do not penetrate deeply and their actions on black skins is probably confined to the surface; and it appears that vitamin D is formed in a film of secretions from the subaceous glands and absorbed from the surface of the skin. That such absorption can take place is indicated by the fact that rachitic puppies can be cured by applying fish-liver oil to their skins.

Some tropical races have the good practice of anointing their children with gingelly or other oil and allowing them to play naked in the sunlight.

Storage of Vitamin D in the Body. There is a considerable store of this vitamin in the body of the well fed. This is important in the case of pregnant women because part of their stores must be transferred to the developing infant. The children of women who have been on diets deficient in vitamin D are particularly liable to

become rachitic, and this liability is increased if the diets have also been deficient in calcium or phosphorus.

Hypervitaminosis. Vitamin D is the only vitamin which has been shown to have toxic effects when taken in excess. Enormous doses in animals are followed by a great increase in the amount of calcium and phosphorus in the blood, and this leads to exaggerated calcification ; the bones become denser, deposits of calcium around the roots of the teeth anchor them to the jaws, the blood vessels become calcified, and these changes when extreme quickly lead to death.

Signs and symptoms in overdosed children have been described as follows : vomiting and diarrhœa with frequent micturition, neuralgia, headache and dizziness with tenderness of the gums and teeth and pain in the muscles and joints ; these quickly disappear with the discontinuance of the drug. As to the toxic dose, the evidence is conflicting, because some of the instances of toxicity appear to have been due to toxic sterols produced in improperly irradiated ergosterol. In the rat, doses up to one hundred times the protective dose do no harm, but much larger doses are definitely injurious. If this is applicable to children the quantity of fish-liver oil necessary to cause harmful effects is so large that a child is unlikely to be given a toxic amount ; but with proprietary preparations of irradiated ergosterol some care is necessary.

Methods of Assay. There are at present no chemical tests for the determination of this vitamin. All estimations are therefore by biological assay testing the amounts needed to cure rickets in animals, and the rat is the animal most frequently used.

Vitamin D in Foodstuffs

The richest sources of vitamin D are fish-liver oils and to a somewhat less degree fish-body oils. Other foodstuffs which have fair amounts are butter, egg yolk and the livers of mammals and birds.

It has been generally believed that vegetable foodstuffs alone cannot supply a sufficiency of vitamin D for a growing child. Doubtless this is correct in respect of foodstuffs grown in temperate climates, but foodstuffs exposed to the sunlight of the tropics

may contain appreciable amounts of vitamin D. It has been found that cocoa butter and even the shell of the cocoa bean are very rich in vitamin D. The beans from the cocoa pod are prepared for the market by fermentation at fairly high temperatures, and then the beans are dried in the sun for several days which activates the 22-dihydrocholesterol of the cocoa butter to produce vitamin D_4.

Further, appreciable quantities of vitamin D have been found in edible fungi and grasses.

The amount of vitamin D in various foodstuffs is given in Table XXXVIII.

TABLE XXXVIII

	Vitamin D			Vitamin D	
	Units per 100 gm.	Units per oz.		Units per 100 gm.	Units per oz.
Fish-body oils . .	200–20,000	55–5,600	Milk (winter) .	0·3–1·7	0·1–0·5
			,, (summer)	2·5–4·0	0·7–1·1
Fish-liver oils . .	2,000–25,000,000	550–7,000,000	Edible fungi .	60–100	17–27
			Cocoa butter .	30,000	8,000
Butter (winter) .	15–30	4–8	,, shells .	3,000	800
,, (summer) .	40–100	12–27	Hay . . .	6	1·7
Eggs (yolk) . . .	100–500	27–140	Grass . . .	7	20
Mammalian liver .	10–50	3–14			

VITAMIN E

Alpha-tocopherol

Mattill and Conklin [1] (1920) found that rats reared on whole milk grew well but were sterile, and they suggested that milk lacked a vitamin needed for reproduction. Evans and Scott [2] (1922) showed that rats fed on a diet containing all known essentials became completely sterile in the second generation, and further, they discovered that the unknown substance was present in fresh lettuce, wheat embryo and dried alfalfa. It was also shown that

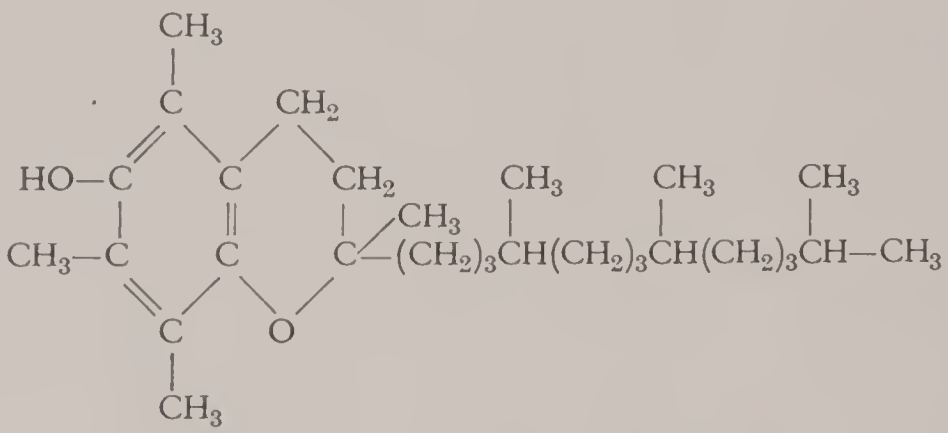
[1] *J. Biol. Chem.*, 44, 137.

[2] *Science*, 56, 650.

the factor in question was fat soluble and Sure [1] (1923) suggested the name vitamin E, and this was universally adopted.

Chemistry. Evans [2] and his associates (1936) isolated several fat soluble alcohols from wheat-germ oil. He called these *tocopherols* (tokos—childbirth ; phero—to bear ; ol—alcohol), and the one which was most active physiologically was named *alpha-tocopherol.* The formula suggested was $C_{29}H_{50}O_2$. Before the structural formula had been worked out, Karrer [3] and his associates synthesized the vitamin by condensation of trimethyl hydroquinone with phytyl bromide, zinc chloride being the catalyst.

The structural formula is :



Alpha-tocopherol is a non-crystallizable yellow oily substance. It is associated in nature with antioxidants which prevent rancidity in oils. And vitamin E is rapidly destroyed as oils become rancid. This may be of some importance in animal husbandry.

Two other tocopherols, β and γ, have biological activity.

Effects of Deficiency in Animals

Vitamin E deficiency in adult rats causes female and male sterility.

Female sterility. Matings are successful with implantation of a fertilized ovum. Development of the fœtus becomes retarded at about the 8th day after gestation, and the fœtus dies on about the 13th day and is resorbed, the process being completed by about the 20th day. This sterility can be cured by ingestion of vitamin E.

Male Sterility. Diets lacking vitamin E cause sterility in adult rats in 90–150 days. The process is much quicker when young

[1] *J. Biol. Chem.*, 58, 693. [2] *Ibid.*, 113, 319.
[3] *Helv. Chim. Acta*, 21, 520.

rats are weaned on the deficient diet ; and quicker still when their lactating mothers have received the deficient diet. There is degeneration and removal of the germinal epithelium of the testes. The germ cells degenerate in the reverse order of their formation, mature spermatozoa disappear before there are marked changes in the epithelium of the tubules. The administration of vitamin E does not lead to regeneration within the tubules, hence this sterility is incurable.

Although female mice lose reproductive power on vitamin E deficient diets as readily as rats, yet male mice appear to require far less of the vitamin proportionally to their size than rats, and on diets deficient in this vitamin they do not readily become sterile.

Muscular Dystrophy. When young rats are suckled by vitamin E deficient mothers they acquire a weakness of the hind quarters which become paralysed. This is due to degeneration and necrosis of the muscles. Under similar conditions puppies will also show muscular dystrophy.

Encephalomalacia. Chickens fed on certain diets containing cod-liver oil develop a staggering gait and marked tremors, and at post-mortem extensive degeneration of the cerebellum is found. This condition can be prevented by the inclusion of α-tocopherol in the diet.

Effects of Deficiency of Vitamin E in Man

The results of animal experiments naturally directed attention to sterility in both sexes, abortion in women and the muscular dystrophies. The administration of large doses of vitamin E or the synthetic α-tocopherol has no effect in sterility or the muscular dystrophies, but there has been a considerable measure of success in treating women subject to habitual abortion from unknown cause. It does not necessarily follow from this that the women with habitual abortion have been consuming diets deficient in vitamin E, the results are more likely to be due to pharmacological action.

Methods of Assay. Biological assay to determine the amount of the vitamin which will prevent the resorption of the fœtus in

vitamin E deficient female rats has been the commonest method used.

Chemical and physical methods, such as that of Karrer[1] and his co-workers, have been proposed.

Units of Measurement

Evans suggested a unit based on biological assay, but it has not been adopted.

At the instance of the League of Nations a London Committee from the Lister Institute and Medical Research Council recommended that the synthetic racemic α-tocopherol should be the adopted *international standard* for vitamin E and the the unit should be 1 *mg.* of this, which is about the average amount which prevents resorption of the fœtus in rats deprived of vitamin E.

Human Requirements

These are unknown, but, judging from animal experiments, 0·35 mg. per kg. body weight may be suggested.

Effect of Storage and Cooking

The vitamin is very stable and is not destroyed by heat up to 200° C., it is not destroyed by aeration or light, it can withstand saponification and hydrogenation of the oil in which it is dissolved. It follows from this that neither processing, storing or cooking food is likely to affect the content of vitamin E. But there is the exception to this general stability, it is easily destroyed by rancidity in oils even when this is slight and produced by autoxidation.

Vitamin E in Foodstuffs

This vitamin is very widely distributed among foodstuffs. Leaves and cereals are particularly rich. About 55 per cent. of the vitamin in cereals occurs in the germ, and the outer coats of the grain are also fairly rich in it, but there is very little in the endosperm, hence white bread and highly milled rice are deficient in it. Wheat-germ oil has been widely used for the therapeutic administration of vitamin E.

[1] *Helv. Chim. Acta*, 21, 1161.

Man is unlikely to suffer from a deficiency of this vitamin. But the possibility of destruction of the vitamin in rancid fats and faulty absorption from the intestine should be borne in mind.

VITAMIN K

(Menadione) (Methyl-naphthoquinone)

A nutritional disease of chickens characterized by numerous hæmorrhages leading to anæmia and death was described in 1929 by Henrick Dam [1] of Denmark as the result of feeding chickens on a fat-free diet. This was confirmed and the disease described in more detail by Holst and Halbrook [2] (1933). Dam [3] (1935) reported that the antihæmorrhagic factor was fat soluble not a sterol and was unsaponifiable, and suggested the name " vitamin K " (Koagulation).

Chemistry. It has gradually been discovered that a number of *quinones* or substances which give rise to suitable quinones in the body, can act as the antihæmorrhagic vitamin or provitamin. A preparation which was found to be highly effective in preventing hæmorrhage in chickens was an hexane extract of alfalfa. A little later it was discovered that chicken food containing fish meal, from which the vitamin K had been extracted, when kept in a moist condition for a few days became protective against hæmorrhages in chickens ; it was apparent that bacterial action had produced vitamin K in the fish meal. The vitamins of alfalfa and decaying fish are two different quinones. In 1939 Almquist and Klose [4] found that the synthetic 2-methyl-1 : 4-naphthoquinone had high vitamin K potency. Thus the first three vitamins K to be recognized were :

(1) Vitamin K_1 2-methyl-3-phytyl-1 : 4-naphthoquinone from alfalfa. This is also called phylloquinone.

(2) Vitamin K_2 is 2 : 3-difarnesyl-1 : 4-naphthoquinone from decaying fish.

(3) Vitamin K_3 is the synthetic 2-methyl-1 : 4-naphthoquinone.

The empirical formula of K_1 is $C_{31}H_{46}O_2$.

[1] *Biochem Ztsch.*, 215, 475.
[2] *Science*, 77, 354.
[3] *Nature*, 135, 652.
[4] *J. Amer. Chem. Soc.*, 61, 1611.

It has been suggested that phthalic acid is the biologically active substance because all vitamins K are easily oxidized to this acid.[1]

The vitamins K are yellow crystallizable substances soluble in oil but insoluble in water. They require bile salts for their absorption from the intestine. Hydrochloride, sulphate and phosphate esters, as prepared synthetically, are water soluble and are absorbed from the intestine in the absence of bile.

Very little vitamin K is stored in the body.

Action. Vitamin K is needed for the proper formation of prothrombin, but the manner in which this is brought about is not known. Prothrombin is formed in the liver and a deficiency of vitamin K inhibits this.

Effects of Deficiency of Vitamin K in Animals

A hypoprothrombinemia follows a deficiency in animals and birds, and the lowered clotting power of the blood leads to hæmorrhages and death.[2]

Effects of Deficiency in Man

Vitamin K deficiency due to a scarcity of it in human diets has not been reported and it is unlikely to occur. But there are two well-marked types of conditioned deficiencies which are followed by hæmorrhagic diatheses.

(1) *Due to Inadequate Intestinal Absorption of Vitamin K.* This is the result either of insufficient bile salts in the intestine, such as occurs after obstruction of the bile duct, or of various intestinal conditions, and among the latter are intestinal obstruction, surgical short-circuitings, dysentery and sprue. In all these conditions there is a deficiency of prothrombin in the blood. In cases of

[1] *Nature*, 151, 586.

[2] There is a disease of cattle known as "sweet clover disease" which arises from the ingestion of improperly cured sweet clover hay or silage. This disease is due to the poisonous substance 3,3-methylene-bis-(4-hydroxycoumarin), called for short *dicoumarin*, appearing in the fodder. The poison is an anticoagulant and causes severe hæmorrhages and the result may be death. Dicoumarin has been given experimentally to many species of animal; and is now used therapeutically as an anticoagulant in cases of thrombosis. Dicoumarin diminishes the prothrombin in the blood and increases the clotting time. It had been reported that the administration of vitamin K counteracts the hypoprothrombinemia of dicoumarin poisoning, but this has been disputed.

obstructive jaundice the prothrombin can be raised to normal by the administration of 2–3 mg. of menadione with 5–10 grains of bile salts daily ; prior to the introduction of this treatment patients undergoing operations for obstruction of the bile passages were at serious risk of severe hæmorrhage. When there is disease of the intestines one or other of the soluble preparations of vitamin K should be given intravenously or intramuscularly.[1]

(2) *Hæmorrhagic Diatheses of the Newborn* (Hypoprothrombinemia hæmorrhagica neonatorum). Hæmorrhages from any part of the body ranging from intracranial hæmorrhage, causing convulsions and death, to bleeding from mucous or serous surfaces may occur in this diathesis.

There is a fall in the prothrombin in the blood in the first few days of life and *hæmorrhagica neonatorum* may be considered an exaggeration, perhaps starting in intrauterine life, of a normal physiological process. The reason for this fall in the prothrombin or why some mothers fail to supply the amount of vitamin K needed by the infant is unknown in most cases. But it is known that barbiturates affect blood coagulability and the administration of any of them such as sodium pentobarbitol to a mother to produce first-stage analgesia during labour increases the hazards of hæmorrhage for the newborn child, and this can be prevented by the administration of vitamin K to the mother.

The amount of prothrombin in the blood of infants starts to increase about a week after birth, and it may be that this is associated with the establishment of bacterial fauna in the intestines, because many bacteria produce vitamin K. This may be an example in the human being of what is called " refection " (*vide* p. 69).

Waddell and Lawson [1] reported that only 1 per cent. of 400 newborn infants, whose mothers had been given vitamin K, had abnormal bleeding, whereas among 219 cases without the vitamin the rate was 10·4 per cent. It has become the practice in some lying-in hospitals to administer vitamin K to every mother at the

[1] Alcholic cirrhosis and other diseases or injuries of the liver may cause a fall in the amount of prothrombin in the blood followed by hæmorrhagic diatheses, but this cannot be corrected by giving vitamin K because the damaged cells of the liver are unable to use it to manufacture prothrombin.

[2] *J.A.M.A.*, 115, 1416.

onset of labour ; this practice is quite harmless to the mother and definitely prevents hæmorrhagic diathesis of the infant. Hæmorrhage in the newborn is usually quickly controlled by giving 2–3 mg. of a soluble preparation of an active quinone parenterally.

The prothrombin time can be determined in cases of hæmorrhagic diathesis by the method of Quick or some modification of it (*vide* Appendix VI, p. 336).

Methods of Assay. Biological assays are based on the cure or prevention of hæmorrhages in animals on vitamin K deficient diets. The chicken is commonly used and the purpose of the assay is to find that amount which will render normal the blood-clotting time of vitamin K deficient chickens under defined conditions and in a specified number of hours. Biological assays for vitamin K are far from satisfactory and are being replaced by more accurate chemical procedures.

Units of Measurement

Several units have been proposed, and an example is the Ansbacher [1] unit ; it is defined as " the minimum amount necessary to render the blood-clotting time of the vitamin K deficient chick, weighing 70–100 gm., normal within 6 hours after administration." But after the introduction of accurate chemical procedures for the analysis of the vitamin and the synthesis of pure forms of it, the need for special units ceases, and the doses of any particular preparation can be stated in milligrams or micrograms (γ).

Human Requirements

The exact amount is not known and appears to be only a few micrograms daily..

Amounts in Foodstuffs

Vitamin K is widely distributed in nature. The richest sources are green leaves, such as spinach and cabbage. Tomatoes are a fair source. Vitamin K is also present in cereals, pulses, roots and fruits, though to a less extent than in green leaves.

[2] *J. Nut.*, 21, 8.

CHAPTER VIII

VITAMINS (*contd.*): CITRIN (VITAMIN P), INOSITOL, CHOLINE, POLYAVITAMINOSIS

VITAMIN P

"Citrin"

In 1936 Szent-György [1] found that Hungarian red pepper and lemon juice contained substances other than ascorbic acid which could control the hæmorrhages occurring in the course of a variety of conditions. It was suggested that these substances were flavonones or flavonone glycosides. Scarborough [2] carried out some experiments on patients who had abnormally high capillary fragility, which appeared from the clinical histories to be related to dietary deficiency. He used various mixtures of known vitamins, and several extracts of flavones from oranges prepared after the methods of Szent-György. A definite increase in the resistance of capillary walls to the application of positive and negative (suction) pressure was obtained only in those instances in which flavonone containing extracts were used, whether given by mouth, rectum or injected. The administration of ascorbic acid failed to produce this beneficial result.

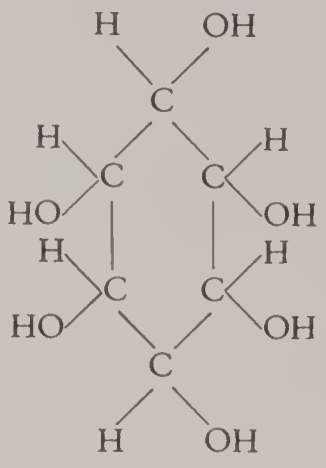
The preparations of Szent-György, called citrin, have been found to contain two active substances which are closely allied to flavonone components named *hesperidin* and *hesparitin*, the latter has been called *eriodictin*. These may be forms of vitamin P, but it is certain that more active forms exist because concentrated water extracts of black currants greatly exceed both these substances in potency.

Inositol

Inositol is a crystalline substance with a sweet taste and is isomeric with d-glucose ($C_6H_{12}O_6$).

[1] *Nature*, 138, 27.
[2] *Biochem. J.* (1939), 33, 1400.

Structurally inositol is a hexa-hydroxy cyclohexane :

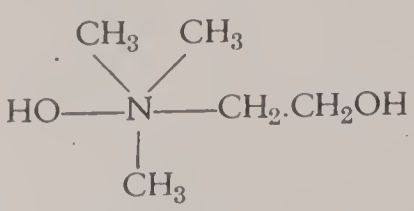


This substance is widely distributed in the organs of the animal body, and in combination with phosphoric acid occurs as phytin in seeds and other vegetable foodstuffs.

Woolley [1] in 1940 was the first to show that when inositol is absent from the diet of mice they develop areas of baldness which is cured when this substance is added to the diet. Later it has been found that inositol is needed for the growth of young rats and mice, and in its absence the former acquire " spectacled eye." But these syndromes occur only when the diets have a low fat content, a generous supply of butter in the diet seems to prevent them ; therefore more investigations are required before inositol can be definitely labelled a vitamin. Nothing is known of the significance of inositol in human nutrition.

Choline

Choline is a colourless viscous fluid, and choline chloride is hygroscopic, white and crystalline. The chemical formula is $C_5H_{15}O_2N_1$, and its structure is :



A dietary deficiency of choline produces in growing rats hæmorrhagic degeneration, especially marked in the kidneys ; there is

[1] *Science*, 92, 384.

also excessive deposition of fat in the liver, and a high increase in the non-protein nitrogen of the blood. The kidneys and liver are almost double the normal weight, and the fat in the liver may increase from a normal of about 5 per cent. to as much as 25 per cent. of the weight of the organ. The onset is acute and a high percentage of the rats die between the 7th and 9th day after they have been on the choline-deficient diet. This condition cannot be produced in rats which have ceased growing.

Methionine or betaine in sufficient amounts in the diet prevent these changes, whereas cystine or cholesterol enhance the effect of choline deficiency. These facts have led to the postulation that one of the functions of choline is to supply labile methyl groups. A methyl group is called labile when it is readily transferable *in vivo* from one organic substance to another. This simple group is involved in lipid, carbohydrate and protein metabolism; and therefore is indispensable for the animal body. It is found in choline, methionine and betaine. The methyl group of methionine is used by the rat for the synthesis of choline and creatine; somewhat similarly the methyl groups of choline may be used for the methylation of homocystine to methionine.

There is a high incidence in Ceylon of stillbirths and deaths a few hours after birth, sections cut from the organs of some of these infants showed much fatty degeneration of the liver and hæmorrhages in the kidney, and other organs. The changes appeared similar to those described by W. H. Griffith [1] for young rats on choline-deficient diets. Dr. Griffith kindly sent the author microscopical sections from the rats, the changes were similar except that there was more cellular degeneration in the organs of the infants. The mothers of the infants had been on diets more or less vegetarian, and three-quarters of the calories were from parboiled rice; these diets were deficient in more respects than one, and certainly had a relatively low choline content. But there are many causes of fatty degenerations and capillary hæmorrhages.

Sure [2] had found that choline is needed for lactation in rats and the prevention of paralysis in suckling rats.

It has long been known that choline is a component part of the

[1] For references see *J. Nut.*, 22, 239.

[2] *Ibid.*, 19, 71.

phospholipid lecithin. The present views are that choline has at least three functions : to take part in the formation of phospholipids, stimulate the production of acetyl choline and to supply labile methyl groups.

Table XXXIX gives the choline content of various foodstuffs. The items have been extracted from a table given by Engol.[1]

TABLE XXXIX

Choline Content of Animal and Plant Products

ANIMAL PRODUCTS

	Choline chloride mg. per gm.			Choline chloride mg. per gm.	
	Fresh	Dry		Fresh	Dry
Beef steak	0·95	3·53	Kidney	3·17	14·10
Brain	3·75	18·20	Liver	5·52	18·35
Chops	0·77	1·81	Milk, fresh	0·147	1·14
Egg yolk	17·31	32·81	Milk, dried skim	1·59	1·63
Egg albumen	—	<0·05	Milk, dried whole	1·07	1·10
Fish, trout	0·87	4·89	Cheddar cheese	0·48	0·70
Fish, snapper	0·84	4·12	Butter	—	<0·05
Ham	0·88	2·00	Cod-liver oil	—	<0·05
Heart	2·31	11·16	Pancreas	3·29	12·60

PLANT PRODUCTS

Cereals :			*Roots* (sundried) :		
Barley	1·39	1·55	Carrots	0·95	1·12
Corn meal	0·42	0·47	Potatoes	1·06	1·31
Oats	0·94	1·00	Potatoes (sweet)	0·35	0·36
Rice (milled)	0·88	1·02	*Leaves :*		
Wheat	0·92	1·01	Cabbage	—	2·90
Wheat germ	4·10	4·40	Mustard tops	—	2·77
White flour	0·52	0·57	Spinach	—	2·75
Pulses :			Turnip tops	—	2·69
Cow peas (dried)	2·57	2·84	Rape	—	2·86
Peas (English)	2·63	2·90			
Peanuts	1·67	1·74			
Soya beans	3·40	3·58			

Folic Acid

Folic acid, so named because of its abundance in leaves, is present in all animal tissues, and this indicates that it is of nutritional im-

[1] *J. Nut.*, 25, 441.

portance. Its isolation was accomplished in 1941 by Williams [1] and his co-workers.

VITAMIN L

Nakahara [2] and his associates reported the existence of dietary factors specific for lactation and named them L and L_1.

POLYAVITAMINOSIS AND THE NOMENCLATURE OF DEFICIENCY STATES

Poor diets are usually deficient in more respects than one, and further, individual reactions to the same deficiencies are very variable, far more than is the case with most infectious diseases. Two examples will serve to demonstrate this :

(1) The first example was in a prison where there were more than 1,000 inmates. At the time of inspection 55 per cent. had phynoderma of various degrees, about 30 per cent. complained of night blindness and there were 17 cases of keratomalacia in the prison hospital. Sore mouth occurred in 18 per cent. and scrotal dermatitis in 16 per cent., but only 44 per cent. with scrotal dermatitis also had sore mouth. A high percentage of the prisoners complained of subjective symptoms indicating neuritis, and some showed definite signs. An eminent physician who examined them made tentative diagnoses of neuritis, poliomyelitis, ataxia and beriberi, which shows how variable the signs were. Thus there were patients who had signs attributable to a deficiency of one vitamin only, but not the same vitamin in all cases, for instance, some had keratomalacia, and others sore mouth or scrotal dermatitis ; again others had signs of more than one deficiency ; and again many had no signs whatever. All the prisoners partook of the same curry and rice diet, and the cooking and serving of the diet precluded the possibility of preferential treatment except for the few working in the kitchens. A study of the length of time each prisoner had been in the jail did not explain why the signs varied among them. It must be concluded that all the prisoners were suffering from clinical or latent polyavitaminosis.

[1] *J. Am. Chem. Soc.*, 63, 2284.

[2] *Inst. Phys. Chem. Res.*, 36, 327.

(2) The second example was among children of the indigent classes. Under war conditions in Ceylon wages went up, the cost of living increased and rationing was introduced. Many persons prospered, others did not, and among the latter were a number of indigents who became definitely poorer, and malnutrition among their children became rife.

Excluding all patients with infections, such as dysentery, thirty consecutive cases of malnutrition were studied in the children's hospital. The following gives the salient signs of ten of these :

(1) Age 2 m. Emaciated, œdema of legs, pigmented conjunctivæ, Bitot's spots, xerophthalmia.
(2) ,, $1\frac{1}{2}$ m. Apathetic, emaciated, angular stomatitis.
(3) ,, $2\frac{1}{2}$ f. Apathetic, emaciated, xerophthalmia, diarrhœa, scabies.
(4) ,, 2 f. Very emaciated, spongy gums (bleeding), early keratomalacia.
(5) ,, 2 m. Œdema, diarrhœa.
(6) ,, 1 m. Œdema, angular stomatitis, glossitis, xerophthalmia, dermatitis of crazy pavement type.
(7) ,, $2\frac{1}{2}$ f. Emaciation, apathy, corneal opacities from keratomalacia.
(8) ,, 3 m. Phrynoderma, slight œdema, blind from keratomalacia.
(9) ,, $2\frac{1}{2}$ f. Emaciated, diarrhœa.
(10) ,, $2\frac{1}{4}$ m. Emaciated, dying with terminal diarrhœa.

The analysis of the more salient signs of malnutrition found among these thirty children is as follows :

Skin		*Eyes*	
Phrynoderma	1	Xerophthalmia	7
Dry skin with mosaic	4	Pigmented conjunctivæ	6
Crazy pavement	1	Bitot's spots	6
Œdema	6	Corneal opacities	2
Mouth		Keratomalacia	2
Angular stomatitis	10	*Apathy*	8
Eroded tongue	3	*Irritability*	4
Spongy gums	2	*Diarrhœa*	5

Many of the children had some degree of anæmia, but there were no advanced cases among them. Subjective symptoms are difficult to determine in children, but several had photophobia sometimes accompanied with lacrymation. Neuritis occurred, but the degree of it was difficult to appraise. It was strange that only one child had phrynoderma, because this eruption, which had declined in

FIG 11.

CRAZY PAVEMENT ERUPTION

FIG. 12.

NUTRITIONAL ŒDEMA

[*To face page* 153

prevalence during the first two years of the war, had again become prevalent among the free school children.

The staple diet of these children had been cereal gruels or white flour and coconut roti. Milk was unobtainable. Doubtless all these children were in a state of polyavitaminosis, even those who showed definite signs of a deficiency of only one vitamin.

An uncommon but well-marked case of polyavitaminosis is shown in Fig. 8, Pl. IV. The patient was a boy of about thirteen years of age, who had a dry skin, phrynoderma, a parchment-like eruption of the face, blindness from keratomalacia, angular stomatitis, glossitis and spastic paralysis of his limbs. Thus the patient had more than one skin eruption due to different deficiencies.

In the light of our present knowledge the variability of the signs of deficiency diseases is not astonishing, rather it is strange that there are nutritional diseases which in some cases are consistent in signs and symptoms; scurvy, beriberi and pellagra are among these. Yet the diagnoses are very forced in many cases which are assigned to one or other of these three diseases.

Various names have been given to indefinite types of malnutrition, especially to those occurring in children. Barlow's disease was the first, and later examples are pseudo-pellagra, infantile pellagra, mandama, kwasiorkhor, culebrilla, Gillan's œdema, pellagroid-beriberi, and there are others.

Much attention has been paid to the *crazy pavement dermatosis* (Fig. 11, Pl. VI) of kwasiorkhor, first described by Cecil Williams[1] in 1933. Trowell[2] gives the following description of this eruption: "The dermatosis is best seen in children who have a pale skin. It appears as dark areas of dark-brown varnish, which have cracked, revealing very pale areas underneath. These islands of dark skin stand out clearly on the pale sea of depigmented skin, and resemble an archipelago. They occur over the pressure areas of the buttocks, ribs, spine, thighs. They peel in moist areas like the groins. They seldom feel very rough, but are harsh and dry to the touch. In adults, a more indefinite type of dermatosis occurs, but roughness and hyperkeratosis are more marked. A few dark plaques of crazy

[1] *Arch. Dis. Child.*, 8, 423. [2] *East African Med. Jour.*, XX, 137.

pavement scales may be seen over the great trochanters, pelvic brim, spines of the vertebræ, ribs and elbows. Less marked areas of crazy pavement are often visible over large areas of the body, and are specially common on the shins as shiny cracked areas of reptilian skin, rather like a mild form of ichthyosis."

The above description appears to include several types of skin changes : A mosaic eruption over the tibiæ, an eczema of the moister parts (either of which may occur in children having chronic ill-health from any cause), a more or less generalized dermatosis with tendency to scale in large plaques (Fig. 11, Pl. VI, p. 153), and various hyperkeratoses. Some of these may be seen in children sufficiently well to attend school and any combination of them in children with marked malnutrition.

There are two general types of stools which may be passed by children with malnutrition, excluding those due to dysentery ; one is slimy and watery, and may be pale, dark or greenish ; the other is soapy and bulky as in cœliac disease.

Post-mortems on malnourished children seldom throw further light upon the subject. In many cases there are signs of secondary infection, such as skin sepsis, bronchitis, pneumonia or dysentery. There is usually hyperæmia and a little erosion of the mucous membrane of the intestinal tract, the liver shows fatty degeneration, and histological examination of the central nervous system reveals changes in the nerves and cord of the subacute combined degeneration type.[1]

Because of the great variability of the manifestations of malnutrition it is doubtful if the specific names mentioned above are of much aid for comprehension.

In one children's hospital all the patients on admission are examined for the following signs and symptoms : wasting, apathy, irritability, nutritional œdema, various types of anæmia, angular stomatitis, eroded tongue, spongy gums, decayed teeth, photophobia, lacrymation, xerophthalmia, pigmented conjunctivæ, vascularization of the sclerotic limbus, keratomalacia, opacities of cornea, signs of rickets, signs of neuritis, diarrhœa and type of stools, various skin eruptions and depigmentation of skin or hair.

[1] Nicholls, L., *Ind. Med. Gaz.*, LXX, 550.

And from this examination an attempt is made to evaluate the general and specific nutritional states.

A great disadvantage of the absence of a nomenclature for many types of malnutrition is that vital statistics are silent on much mortality of nutritional origin, and the deaths are attributed to terminal conditions, such as broncho-pneumonia, dysentery and skin sepsis.

Any nomenclature for malnutrition must be elastic ; and perhaps the use of letters in naming vitamins may be continued for this purpose. For example, in cases where the signs indicate a deficiency of vitamins A and C or vitamins D and B_2 they would be referred to as avitaminosis AC and avitaminosis DB_2 respectively.

Starvation

The signs of starvation are wasting of the subcutaneous fat and muscles, pallor, glazed skin, exhaustion and weakness. Usually the depletion of the proteins of the body leads to œdema of the lower extremities or the whole body. Albuminuria is a common sign, and although it may be due to some damage of the kidneys, when the patient receives a sound diet it disappears and does not lead to chronic nephritis.

Frank signs of vitamin deficiencies are not common in acute or sub-acute starvation, probably because the vitamins stored in the body or supplied in the small amount of food taken are sufficient for the diminished metabolic processes. But signs of beriberi, scurvy, or riboflavin and vitamin A deficiencies sometimes occur.

Note. The depigmentation which has been described in Africa may possibly be due to pantothenic acid deficiency or some other deficiency which causes acromotrichia in rats.

CHAPTER XI

CONDIMENTS, BEVERAGES AND "ROUGHAGE"

Condiments

Condiments are used in far greater quantities in the tropics of the East than in temperate climates. In India and other countries a liquid preparation of condiments is called a curry, and one of fairly solid consistency is called a sambol. The basis of most curries is the grated coconut kernel emulsified in water and known as coconut milk (*vide* p. 228), and varying proportions of chillies and other condiments are cooked in this milk.

Table LX (p. 196) is a list of the more commonly used condiments, and there are many others in which the active principle is an essential oil, such as dill (*Anethum graveolus*), anise (*Pimpinella anisum*), fennel (*Fœniculum fœniculum*), and a number of aromatic leaves of which the following three are widely used : curry leaves (*Murraya kœnigii*), screw pine leaves (rampay) (*Pandanus latifolium*) and lemon grass (sera) (*Cymbopogon* (*andropogon*) *citratis*.)

The condiments are not taken for their food values in terms of proteins and carbohydrates and bring only trifling amounts of these to the sum total in most diets, but they may increase somewhat the vitamins in a diet.

The condiments may be considered under three headings : the effects on smell and taste ; the definite values ; and the abuses of them.

(1) *The Effects on Smell and Taste.* The labouring classes use a few condiments, and the dried chilli is always pre-eminent among them ; but the curries of the wealthier classes may contain a bewildering assortment of condiments to fascinate jaded appetites. The ingredients of even the simpler curries produce various effects on smell and taste.

The alkaloids of the chillies and peppers cause a sensation usually called " hot " ; the essential oils produce an aroma and pungency ; tamarind, limes, and perhaps vinegar, give an acid tartness ; some of the gum resins and other bodies are bitter ; and asafœtida,

fenugreek and fragments of dried partly decayed fish supply a fœtor pleasing to many.[1]

(2) *Definite Values of Condiments.* The labouring classes of the tropics must subsist on cheap, tasteless and montonous diets, and these will undoubtedly give rise to anorexia unless the appetite is stimulated by the sting of chillies and peppers and the aroma and pungency of other condiments.

Many of the condiments have a carminative effect and lessen flatulence which without them might arise from pulses and coarse vegetables. Rice stained yellow with turmeric is popularly credited with considerable carminative properties.

The amounts of vitamins supplied by condiments and other curry stuffs may be illustrated by the following example of a daily portion prescribed for the ordinary diets of an "Eastern" hospital :

The daily portion per person consisted of:

Coconut kernel	4 oz.	Ginger	0·1 dr.
Red onions	0·5 ,,	Pepper	0·2 ,,
Dried chillies	0·25 ,,	Tamarind	1·5 ,,
Garlic	1·4 dr.[2]	Goraka	1·0 ,,
Curry leaves	0·2 ,,	Maldive fish	2·5 ,,
Screw pine leaves	0·2 ,,	Mustard	1·4 ,,
Lemon grass	0·1 ,,	Cinnamon	0·1 ,,
Turmeric	0·4 ,,	Dill seed	0·7 ,,
Coriander	1·5 ,,	Lime juice	5 ml.
Cummin seed	3·0 ,,		

This daily portion of currystuffs contains about 100 units of vitamin A and about 9 mg. of vitamin C.

(3) *Abuses of Condiments.* The use of curries and sambols is greatly abused in many countries of the East. Diabetes and cirrhosis of the liver are very prevalent among people who partake of curries and sambols at every meal. Cases of cirrhosis of the liver are six or more times commoner in the post-mortem rooms of the hospitals of India, Java and Ceylon [3] than in those of the hospitals in Great

[1] This may appear strange, but it has its counterpart in cosmetics where the oily excretion from the preanal gland of the civet cat (*Paradoxurus*) has a high market value as an ingredient (in high dilution) of perfumes and cosmetics ; but the excretion as it comes from the civet has a disgusting and revolting stench.

[2] Avoidupois weights, 1 dr. = 2 gm. approx.

[3] Trimitri and Rao (1934), *Ind. Med. Gaz.*, 59, 74 ; Bonne *et al.* (1931), *Genneske. Tijdschr. Neder-Ind.* ; Tyagaraja (1937), *Cey. J. Sci.*, IV, 119.

Britain ; and further pre-cirrhotic conditions are still more common and occur even among older children and adolescents. The cause of this is not known definitely, but most of the cases occur among those who do not take alcohol, and it seems probable that the continual consumption of " hot " curries has much the same effects as some alcoholic beverages in causing a chronic gastritis which leads to cirrhotic changes in the liver, or perhaps some of the irritants of the currystuffs may be absorbed and act directly on the liver. It is noteworthy that alcoholism among those who are addicted to heavy meals of " hot " curries leads far more quickly to cirrhosis of the liver than in those who take similar amounts of alcohol but restrict themselves to the blander diets of Europe. It may be that alcohol and the condiments enhance each other's effects in producing gastritis. Some of the irritants of the curries are more soluble in dilute alcohol than in water, and apart from this, alcohol increases the absorption of them, and this may result in a direct damaging action on the cells of the liver.

Many workers [1] have produced cirrhosis of the liver in animals by nutritionally defective diets, and prevented the fibrosis by the addition of yeast. No particular vitamin has been indicated as being specially needed for the health of the liver. Not only may dietary deficiencies produce cirrhosis but it has been shown that they render the liver more susceptible to the effects of various toxic substances.

It may be that cirrhosis of the liver among the labouring classes of South Asia is due to a combination of irritant condiments and defective diets. There is increasing evidence that low-protein diets, especially if they are deficient in methionine, are an actual or predisposing cause of liver damage (*vide* p. 23).

Diabetes is not common among the labouring classes, but is very prevalent among the upper classes, this is especially the case among fairly prosperous tradesmen, and in some communities glycosuria is more often the rule than the exception among those who have passed middle age. The greater prevalence of diabetes among the well-off classes is due to a breakdown of the carbohydrate metabolism following the use of unnecessarily large quantities of farinaceous foods such as rice, and this overeating is usually brought about

[1] For references see *J. Am. Med. Ass.*, 121, 715.

by the excessive use of condiments ; and therefore indirectly condiments are the cause of diabetes.

Beverages : Tea, Coffee, Cocoa, Maté

Tea. The three important constituents of tea are tannin, caffeine and an essential oil. The aroma of tea is partly due to the essential oil.

When Indian or Ceylon tea leaves are infused in the usual manner about 25 per cent. of the contents of the leaves go into solution, and about 2·5 per cent. is caffeine, 7·5 per cent. tannin and the remaining 15 per cent. consists of various extractives. There is somewhat less soluble matter in China teas, and they contain a little less caffeine and nearly 2 per cent. less tannin.

A large cup of tea (about 150 c.c. or $\frac{1}{4}$ pint) made from 5 gm. (about $\frac{1}{6}$ oz.) of dried Indian leaf contains about 0·1 gm. ($1\frac{1}{2}$ gr.) of caffeine and 0·3 gm. ($4\frac{1}{2}$ gr.) of tannin.

Caffeine is very soluble and most of it goes into solution in a few minutes after boiling water has been poured on the leaf ; but the tannin is less soluble and there is about 20 per cent. more tannin in the hot water after it has remained on the leaves for 15 minutes than in hot water which has remained on the leaves for only 5 minutes. A second brew from tea leaves, even when it has a dark colour, contains very little caffeine and not much tannin.

Coffee contains less caffeine and tannin than tea and the aroma is imparted to the beans when they are roasted because of the formation of a pungent oil called caffeol. A cup of coffee, however, contains much the same amount of caffeine and a little less tannin than a cup of tea, because more coffee is used than tea in making the beverage.

Cocoa contains about 0·5 per cent. of caffeine and about three times as much (1·5 per cent.) of the closely related alkaloid *theobromine.* There is tannin in cocoa but it appears to be in an inert form.

Maté, also called *Yerba, Paraguay tea* or *Jesuit tea,* is prepared from the leaves of *Ilex paraguayensis.* This beverage is widely used on the South American Continent. The leaves contain about 2 per cent. of caffeine and about 11 per cent. of tannin ; also glycosides, choline and ethereal oils are present.

Tea and coffee have a delaying effect on the digestive processes in the stomach, but this is unimportant to persons in normal health. Cocoa is the best beverage to those subject to dyspepsia, or for sick persons.

Alcoholic beverages

The active constituent of alcoholic beverages is ethyl alcohol. It is produced by yeast during the fermentation of sugar according to the equation :

$$\underset{\text{Sugar}}{C_6H_{12}O_6} = 2CO_2 + 2\underset{\text{Alcohol}}{C_2H_5OH}$$

Alcoholic liquors fall into five categories : beers, spirits, wines, fortified wines and strong liqueurs. The alcoholic contents and the caloric values of these are given in Table XL.

TABLE XL

	Alcohol per cent. by volume	Calories per oz.		Alcohol per cent. by volume	Calories per oz.
Beers :			*Wines :*		
Bottled beer . .	5·6	11	Champagne . .	10–15	20–30
English draught beer . . .	5·0	10	Burgundy . . .	10–13	20–26
German beer . .	3·5	7	Claret	10–13	20–26
Spirits :			*Wines fortified by the addition of spirits :*		
Brandy, Gin, Rum, Whisky . . .	33–45	66–90	Sherry, Port, Madeira . . .	17–23	34–48
			Strong liqueurs . .	44–48	88–96

Beers vary considerably in the amounts of alcohol they contain and the figures given in Table XL are rough averages.

Toddy and Native Beers

Toddy is the fermented sap of palm trees, and as usually drunk is a milky fluid due to suspended yeast and various bacteria. The alcoholic content is much the same as that of beer. *Native beers* are

produced by the fermentation of millets or various other grains. Usually the grains are allowed to sprout before being prepared for fermentation. These preparations may be of dietary value, because they are not clarified and much yeast remains in them, and this may correct vitamin deficiencies in the local diets. The beers from sprouted grain are rich in vitamin C.

Alcohol in moderate doses aids digestion because its irritant action stimulates the stomach ; it increases the absorption of other substances, and does not interfere with the action of the digestive juices of the stomach. Almost all the alcohol is absorbed from the stomach and therefore does not reach the intestines. In large intoxicating doses, however, some of the alcohol reaches the intestines where it has an inhibitory action on the tryptic digestion.

After absorption alcohol dilates the capillaries of the skin and this may induce sweating, in any case there is increased loss of heat ; this may be partly counteracted by the fuel value of alcohol, heat being produced as it is burnt up in the body. But alcohol should never be taken under the impression that it " keeps out the cold," for, indeed, it has the opposite effect.

The purple nose and cheeks of the drunkard are due to the continued stimulation of the capillaries of the skin, whereby new capillaries are produced, and both old and new become permanently dilated. The bloated appearance of heavy drinkers is partly due to the fat-sparing effects of alcohol. It may be considered a food to the extent that it supplies calories which otherwise must be supplied by carbohydrates and fats.

Alcohol is a depressant of the brain and its first action is to cut out the highest psychic centres which have been trained through childhood and adolescence for the control of conduct. This removal of inhibitions makes the verities of life less apparent, dispels nervousness and encourages loquacity. But much that appears brilliant, when spoken or written under the influence of alcohol, on the morning of the next day turns to dust.

The lower parts of the brain are depressed by alcohol taken in large quantities, and this leads to inco-ordinate movements ; and after very large amounts of alcohol a man may become truly " paralytic drunk."

It is a very prevalent custom in the tropics for men and women to take alcoholic drinks in the early evening ; these are commonly called " sundowners." Provided these drinks are taken after the setting of the sun or at meals and are limited to three or four half-pegs of whisky (stingers, splits) or the equivalent in other beverages, we may agree with Matthew Arnold : " Wine used in moderation seems to add to the agreeableness of life—for adults at any rate—and whatever adds to the agreeableness of life adds to its resources and power."

Moderation is a relative term, and some men who lead active lives may be able to consume 4 or 5 oz. of whisky daily without deleterious effect to their health, whilst others may enjoy the best health only when total abstainers.

The frequent imbibing of pegs of spirit throughout the day is a pernicious habit which definitely shortens the span of life.

Alcoholism is more frequent among Europeans in the tropics than in temperate climates, and men who take $\frac{1}{2}$–$1\frac{1}{2}$ bottles of whisky, or its equivalent, daily are not uncommon. On an average these men shorten their lives by 20 years, and die between the ages of 50 and 65 ; even the most robust, who might have an expectation of 90 years, do not reach the age of 70.

" Roughage "

Matter resistant to digestion is required to give bulk to the food, to stimulate intestinal movement, and form the mass of the fæces. Foods, which on digestion leave very little residue, such as milk, refined flours and fruit juices, are needed by patients suffering from certain diseases, particularly those of the intestines, including typhoid and dysentery. But persons in normal health require more residue to prevent intestinal stasis and constipation. The term " roughage " is applied to all material in the food which resists the digestive enzymes. It is not a satisfactory term because although coarse fibres and hard particles occur in foodstuffs of both animal and vegetable origin, much of the substance of fæces contains hemicellulose, pectins and other matter of a bland and homogeneous nature which are rough in no sense of the term.

CHAPTER X

ENERGY VALUE OF FOODS. STANDARD ALLOWANCES

The energy of food comes from carbohydrates, fats and proteins, and is expressed in terms of heat units called *calories*.

The *calorie*[1] used in nutritional work is the amount of heat required to raise the temperature of 1 kg. of distilled water 1° C.

The apparatus which has been commonly used for the determination of calorie values, in Atwater's bomb calorimeter (see Appendix VII, p. 338).

The heat of combustion of organic substances depends upon their chemical composition. One gramme of carbon yields 8·08 calories and 1 gm. of hydrogen 34·5 calories; the burning of a compound of carbon and hydrogen, such as petrol, produces much the same amount of heat as would be given off if the elements were burnt separately.

The carbohydrates and fats being composed of carbon, hydrogen and oxygen, may be considered to be already partly oxidized, and therefore the combustion of them does not cause as much heat as the equivalent amounts of carbon and hydrogen which they contain; for instance, 100 gm. of glucose contains 40 gm. of carbon, 6·7 gm. of hydrogen and 53·3 gm. of oxygen and yields much less heat on burning than is given off when 40 gm. of carbon and 6·7 gm. of hydrogen are burnt.

The energy-producing constituent of foodstuffs on complete oxidation in a calorimeter yield the following averages:

Carbohydrates	. .	4·1	calories per gramme
Fats	. . . .	9·45	,, ,, ,,
Proteins	. . .	5·65	,, ,, ,,

The carbohydrates and fats are completely oxidized in the body; but the proteins, which burn in a calorimeter to carbon dioxide,

[1] At one time the calorie was spelt with a capital C to distinguish it from the smaller calorie which is the amount of heat required to raise 1 gm. of water 1° C.

water and nitrogen, are not completely oxidized in the body, and their end products, such as urea, still have energy values which are estimated at about 1·3 calories for each gramme of protein used in the body.

Small amounts of the food materials are lost during digestion, and the average amounts lost on a mixed diet are : carbohydrates, 2 per cent. ; fats, 5 per cent. ; and proteins 8 per cent. The figures which are used in practice for calculating the calorie values of food are :

Carbohydrates and proteins .	4 calories per gramme
Fats	9 „ „ „

The Energy Requirements of Man

The total energy requirements of the body are conveniently expressed in terms of calories per day.

Four methods have been used for determining these requirements of man :

(1) By calculating the calorie value of the food of persons who are maintaining their normal weights.

(2) By determining the amount of oxygen consumed ; this requires an elaborate apparatus.

(3) By determining the balance of intake and output of carbon and nitrogen. The intake is calculated from the amounts of these elements in the food and the output from the amounts of carbon dioxide excreted from the lungs, and the quantity of both elements in the urea and other substances excreted in the urine and fæces. In adults there should be equilibrium between the intake and output.

(4) By measuring the heat given off by the body. The calorimeters used are expensive and complicated.

The quantities of food in terms of calories which are needed to support normal metabolic processes may be considered from three aspects, using one or more of the above methods :

(1) The requirements for *basal metabolism* when a person in normal health is at complete rest in bed in surroundings of comfortable temperature, and has not taken food for twelve hours.

(2) The requirements for general maintenance when a person is living a sedentary life and is not undertaking any active muscular work.

(3) The requirements for work.

The *basal metabolism* is affected by many factors.

(1) *The Size and Shape of the Body.* Although large men usually require more food to maintain basal metabolism than small men, the amount varies far more with the area of the body surface than with the weight ; so that a thin sparse man, having a relatively large body surface, requires more food per unit of weight than a stout thick-set man.

(2) *Exercise.* Those who are accustomed to much muscular activity have higher basal metabolic rates than those who lead sedentary lives, and this is apart from the energy requirements of their voluntary activities.

(3) *Age and Sex.* Children have somewhat higher rates than adults, and there is an increase starting at about the age of ten which continues during puberty. The adult rate is fairly uniform until middle age, when a decrease sets in and continues during the later decades of life. Males have a higher basal metabolism than females.

(4) *Diet.* Those on a high protein diet have a higher basal metabolic rate than those on a high carbohydrate low protein diet.

(5) *Climate.* The inhabitants of the tropics have a metabolic rate about 10 per cent. lower than that of the peoples of temperate climates.

(6) *Pregnancy.* There is an increased rate during pregnancy due entirely to the metabolism of the growing fœtus.

(7) *Disease.* Some internal secretions influence the basal metabolism. In hyperthyrodism the increase may be as much as 75 per cent., whereas in myxœdema it may be reduced by 30 per cent. There is an increase in fevers on an average about 6 per cent. for each degree Fahrenheit.

It is customary to give the food requirements in terms of the calories needed by a man or woman of average weight, and the weights adopted for temperate climates are 70 kg. (154 lb.) and

56 kg. (123 lb.) respectively. The energy requirements of a man of this average size are :

	Lusk's estimate (calories)	*Estimate for tropical people (calories)*
Absolute rest in bed without food . .	1,680	1,500
Absolute rest in bed with food . . .	1,840	1,640
Rest in bed 8 hours, sitting in a chair 16 hours with food	2,168	1,950

Lusk's estimate is too high for most of the races of small men living in the lowlands of tropical countries and the second column above gives an estimate for these.

Standard Allowances for Prescribed Diets

The number of calories and the amounts of the various constituents of foodstuffs which should be allowed when prescribing diets are much contested matters.

Standard allowances must be based on physiological requirements, but it has been customary to recommend somewhat larger amounts so that there is provision for a margin of safety.

The Health Committee of the League of Nations appointed sixteen well-known professors and nutritionists to form a Technical Commission, and in their "Report on the Physiological Bases of Nutrition," Vol. II (1936), they give the following :

From "League of Nations Commission's Report."

"1. *Calorie Requirements :*

(*a*) An adult male or female, living an ordinary everyday life in a temperate climate and not engaged in manual work, is taken as the basis on which the needs of other age-groups are reckoned. An allowance of 2,400 calories net [1] per day is considered adequate to meet the requirements of such an individual.

(*b*) The following supplements for muscular work should be added to the basic requirements in (*a*) :

Light work, up to	75	calories per hour of work
Moderate work, up to . . .	75–150	" " "
Hard work, up to	150–300	" " "
Very hard work, up to . . .	300	" " "

(600 calories may be taken as an average supplement for muscular work.)

[1] The term "net calories" refers to the amount of energy available from the food actually assimilated.

(*c*) The energy requirements for other ages and for mothers can be obtained from the following table of coefficients :

Age (years)	*Coefficient*	*Calories*	*Age (years)*	*Coefficient*	*Calories*
1–2	0·35	840	7–9	0·7	1,680
2–3	0·42	1,000	9–11	0·8	1,920
3–5	0·5	1,200	11–12	0·9	2,160
5–7	0·6	1,440	12–15	1·0	2,400
			15 (upwards)	1·0	2,400

(The co-efficient of 1 from the age of 12 is to meet the needs of puberty.)

The muscular activities characteristic of every healthy child and adolescent necessitates additions to the basic requirements shown in (*c*). It is suggested that the activities of children of both sexes from 5 to 11 years be considered as equivalent to light work, of boys from 11 to 15 as moderate work and of girls from 11 to 15 upwards as light work.

Women	*Coefficient*	*Calories*
Pregnant . .	1·0	2,400
Nursing . .	1·25	3,000

Allowance must also be made for women engaged in household duties whether pregnant or not ; these have to be reckoned as equivalent to light work for eight hours daily.

The requirement for babies under 1 year are difficult to specify except in terms of body-weights ; the following allowances are considered adequate :

Age (months)	*Calories per kilogramme body-weight*
0–6	100
6–12	90

(2) *Protein Requirements :*

In practice, the protein intake for all adults should not fall below 1 gm. of protein per kilogramme of body-weight. The protein should be derived from a variety of sources, and it is desirable that a part of the protein should be of animal origin.

During growth, pregnancy and lactation, some animal protein is essential, and in the growing period it should form a large proportion of the total protein.

The following allowances of total protein are recommended :

Age (years)	*Grammes per kilogramme of body-weight*	*(Age years)*	*Grammes per kilogramme of body-weight*
1–3	3·5	17–21	1·5
3–5	3·0	21 upwards	1·0
5–12	2·5	*Women*	
12–15	2·5	Pregnant 0–3 months	1·0
15–17	2·0	,, 4–9 ,,	1·5
		Nursing	2·0

(3) *Fat Requirements :*

Fat must be a constituent of the normal diet, but the data at present available do not suffice to permit a precise statement of the quantity required. The high content of vitamin A and/or D in certain fats justifies their use in liberal amounts.

(4) *The Influence of Climate on Dietary Requirements :*

In cold climates the energy content of the diet may need to be increased. Where climatic conditions or social customs do not permit of exposure to sunshine, vitamin D should be supplied in the diet.

Dietary Scheme for the Pregnant and Nursing Woman

A. Protective Foods : *Food*	*Amount gm.*	*Protein gm.*	*Calcium gm.*	*Phosphorus gm.*	*Calories*
Milk	1,000	32	1·2	0·9	660
Meat (or fish or poultry)	120	22	—	0·3	240
Eggs (one)	50	6	—	0·1	70
Cheese	30	8	0·3	0·2	125
Green and leafy vegetables	100	1	0·1	—	30
Potatoes	250	6	—	0·2	250
Legumes (dried)	10	2	—	—	35
Cod-liver oil	3·5	—	—	—	30
Available source of vitamin C (raw fruits, etc.)					
B. Supplementary Energy-yielding Foods to meet Individual Energy Requirements :					
Cereals as needed :					
Highly milled	250	28	—	0·2	1,000
or					
(Whole grains	250	—	0·1	0·9	1,000)
Total yield	—	105	1·7	2·8	3,440
Fats and sugar as needed					

Dietary Scheme for Children

Children age 1–2 years (840 calories)

A. Protective Foods: Food	*Amount* gm.	*Calories*	*Protein* gm.
Milk	750	490	24
1 Egg (or equivalent as 30 gm. meat or fish or liver)	48	70	6
Green leafy vegetables	30–60	15	—
Potato (or carrot)	30	30	—
Cod-liver oil	3	30	—
B. Supplementary Energy-yielding Foods:			
Fats (butter if possible)	7	50	—
Cereals (calculated as bread)	50	150	7
		835	37

Children age 2–3 years (1,000 calories)

A. Protective Foods:			
Milk	1,000	660	32
1 Egg (or equivalent, as 30 gm. meat or fish or liver)	48	70	6
Green leafy vegetables	30–60	15	—
Potato (and other root vegetables)	50	50	1
A source of vitamin C (fruit)			
Cod-liver oil	3	30	—
B. Supplementary Energy-yielding Foods:			
Fats (butter, if possible)	10	75	—
Cereals (calculated as bread)	50	150	7
		1,050	46

Children age 3–5 years (1,200 to 1,300 calories)

A. Protective Foods:			
Milk	1,000	660	32
1 Egg (or 30 gm. meat or liver or fish)	48	70	6
Green leafy vegetables	60–100	20	2
Potato (or other root)	100	100	2
Cod-liver oil	3	30	—
A source of vitamin C (raw vegetable or fruit)			
B. Supplementary Energy-yielding Foods:			
Fat (butter, if possible)	15	110	—
Cereals (calculated as bread)	75	225	11
		1,215	53

Dietary Schemes for Children (*contd.*)

Children age 5–7 years (1,400 calories)

Food	*Amount* gm.	Calories	*Protein* gm.
A. Protective Foods:			
Milk	1,000	660	32
Egg	48	70	6
Meat, fish, liver or cheese	30	40	6
Green leafy vegetables	100	30	3
Potato (or other root)	150	150	3
Cod-liver oil	3	30	—
A source of vitamin C (raw vegetables or fruit)			
B. Supplementary Energy-yielding Foods:			
Fats (butter, if possible)	20	150	—
Cereals (calculated as bread)	100	300	14
		1,430	64

Children age 12–14 years (2,600 calories (girls), 3,200 calories (boys))

A. Protective Foods:			
Milk	1,000	660	32
Egg	48	70	8
Meat, fish, liver or cheese	90	120	18
Green leafy vegetables	250	75	7
Potato (or other root)	300	300	6
Cod-liver oil	3	30	—

B. Supplementary Energy-yielding Foods:
Fats (butter, if possible). Cereals and other foods to furnish total calories as required."

The wealthier classes throughout the world will be able to afford these diets; and also they may be obtainable by the labouring classes in a few countries of the temperate zones, and in some mountainous areas in the tropics. But such diets have never been produced in sufficient quantities to serve more than a small percentage of the labouring classes of the lowlands of the tropics.

Whilst keeping the possibilities of future progress in view, recommendations must be capable of practical application.

It may be that the recommendations of the Commission of the League of Nations are a counsel of perfection. (But well-fed women and children do not need a daily dose of cod-liver oil.)

There are reasons to believe that good growth and health may

be achieved on far cheaper diets in which most of the foodstuffs are of vegetable origin.

It has yet to be shown that diets, which will produce the greatest amount of growth during the years of a child's upbringing, are necessarily optimum diets for his future health, activities and longevity.

It may be that a man's health is best served by the consumption for a period of time of diets of calorie and other values somewhat higher than satisfy the requirements of maintenance and work, and these being followed by moderate abstinence on more restricted diets. It is possible that the building up of high reserves followed by a moderate depletion of them is better for man than a persistent maintenance of high reserves. This is certainly in accordance with the dietary habits of many peoples—times of feast being followed by times of abstinence. But this does not mean that the nutritionist may subscribe to periods of semi-starvation among any population, for moderate abstinence is not starvation.

A vast and valuable knowledge has been acquired from experiments on animals leading guarded and inactive lives in the confines of small cages ; and this has been supplemented by balance experiments on human beings, and many of these have been carried out on well-fed and enthusiastic volunteers in temperate climates.

There is, however, a great need for dietary surveys and balance experiments among many peoples with various modes of life and dietary habits in different parts of the world ; and these must be studied with their growth rates, general health and mortality.

Biological adaptations have probably taken place in many races, whereby some races more readily than others absorb and utilize certain dietary constituents. Such adaptations take place only as the result of stresses, periodically occurring through generations. A pastoral tribe or a meat and fish-eating race such as the Eskimos, who have always presented a sufficiency of vitamin A or calcium in very available forms to their bodily economies, are unlikely to be able to utilize carotenes or calcium phytate as readily as more or less vegetarian tribes. Balance experiments among tribes of different dietary habits might give very revealing results, especially if carried out on individuals who had been more or less

on the brink of starvation so that the experiments would not be complicated by too great reserves within their bodies.

The diets of many backward races are suitable for the circumstances under which they live, but may be most unsuitable for the labours and calls of a higher civilization. An African villager may pass his time divided between alternate periods of moderate activities and almost complete idleness, and his normal diet, especially if he belongs to a pastoral tribe, will be quite unsuitable for gang work under a European taskmaster.

It is necessary to propose *Standard Allowances* which are practical for application among the masses of the tropics. What are often called " optimum requirements " are not practicable ; and it may be that minimum requirements are very near the optimum.

Calories

The mean weights of the young men and women of most of the races of Southern Asia and many other tropical lands are about 52 kg. (115 lb.) and 46 kg. (100 lb.) respectively. It follows that 2,400 calories are too high for a maintenance allowance and 2,100 *calories* are sufficient. Again, a cold climate is stimulating for work, and the average labourer expends more energy in a given time than would be the case if he was working in a hot and moist atmosphere. The energy value of the food of the average labourer in the tropics may safely be placed at 2,500–2,600 calories, *provided the diet is sufficiently balanced for good utilization.* A labourer on hard work will require more than 2,600 calories.

Table XLI gives the scale of coefficients and requirements of

TABLE XLI

	Coefficient	*Calories*
Males of 14 years of age and over	1·0	2,600
Females „ „ „ „	0·8	2,100
Children 12 and 13 years	0·8	2,100
„ 10 „ 11 „	0·7	1,800
„ 8 „ 9 „	0·6	1,600
„ 6 „ 7 „	0·5	1,300
„ 4 „ 5 „	0·4	1,000
„ 2 „ 3 „	0·3	750
Pregnant women from 5th month	1·1	2,900
Nursing women	1·1	2,900

calories for practical nutrition work in the tropics. The figures are for food as consumed.

Lactation. The milk secreted by women ranges on an average from about 500 ml. daily for the 1st month after parturition to about 1,000 ml. for the 5th month. This represents 350–700 calories daily.

It is a practice in good stock farming to increase the amount of food during the last three months of gestation. If this is not done the milk yield is affected. This is applicable to women, and insufficient food will lead to failure of lactation.

Proteins. Digestive utilization and biological values vary with different proteins, therefore it is not possible to give exact figures for standard allowances, but they must be above theoretical requirements.

There has been an adage among nutritionists of temperate climates : " Look after the calories and the proteins will look after themselves." This may not be applicable for the conditions in many parts of the tropics, especially where the staple article of diet of the masses is rice, which is the poorest in proteins of all cereals.

It is not entirely satisfactory to base the allowances for proteins on the weight of the individual ; for instance, a child heavy with fat certainly does not need more protein than a lighter child of similar age and build, and the same applies to adults.

The allowances suggested by Aykroyd for India may be accepted as a guide for practical nutrition work in the tropics ; these are given in Table XLII :

TABLE XLII

Sex and Age		*Coefficient*	*Grammes per day*
Man	18–60	1·00	65
Woman	18–60	0·85	55
Boy	10–17	1·20	80
Girl	10–17	1·10	70
Child	6–9	0·90	60
Child	2–6	0·60–0·80	40–50
[1] Pregnant woman after 5th month		1·20	80
[1] Lactating woman		1·30	85

[1] Not given by Aykroyd.

It is desirable that at least one-fifth of the protein in all diets should be of animal origin, and during growth, pregnancy and lactation not less than one-third should be of animal origin.

Fats. The amount of fats in a diet for an adult should not fall below 50 gm. a day. If it is possible butter or ghee should appear in the diets of children and nursing mothers.

Carbohydrates. The main function of carbohydrates is to supply calories. Supposing a diet is to furnish 2,600 calories, and 65 gm. of protein ($65 \times 4 = 260$ calories) and 50 gm. of fat ($50 \times 9 = 450$ calories) provide 710 calories, then the remaining 1,890 calories should be supplied by 472 gm. of carbohydrates.

In all cases where *additional energy is required for work*, it should be supplied by foodstuffs rich in carbohydrates such as rice, bread, or other cereal food, to a very small extent by fat such as vegetable oils or ghee, and as little as possible by flesh foods.

Minerals

Calcium and Phosphorus. The recommended diets of the Commission of the League of Nations contain for children of 1–2 years about 1 gm. of calcium, for older children about 1½ gm. and for pregnant and nursing mothers about 2 gm.; in all cases the amount of phosphorus is a little more. Considerably more than half of the calcium and about half of the phosphorus is supplied by the milk. Calcium and phosphorus requirements have been discussed in Chapter II, p. 34, and standard allowances suggested for calcium are given in Table XVI.

The ratio of calcium to phosphorus and vice versa should not be greater in the diets than 1 : 2.

Iron. The content of iron in vegetable products largely depends on the amount in the soils in which they have been grown, and in localities where the soils are rich in iron there is unlikely to be a deficiency in the diets.

All iron taken in with the food is not available for hæmoglobin formation, and the availability depends on the nature of the iron compound in each foodstuff. Table XLIII gives roughly the percentage of iron available in four classes of foods.

About 8 mg. of *available* iron daily is sufficient for a man, and similarly about 10 mg. for a woman (*vide* p. 45).

TABLE XLIII

Percentage of Iron Available

Leaves	20–30	Meats	50–75
Cereals	50–60	Pulses	60–80

Iodine. When there are intermittent supplies of iodine in the food above the body's needs the excess is stored against future use; and periods of deficiency, unless of long duration, give rise to no obvious ill effects.

It is unnecessary to take this mineral into account in ordinary nutritional practice in areas where goitres due to iodine deficiency are known not to occur.

Orr and Leitch gave the needs of the adult at 0·045 mg. of iodine daily, which is higher than other estimates (*vide* p. 52).

Vitamins. The requirements of these, on which the standard allowances are based, have been considered in previous chapters.

Table XLIV summarizes the average standard allowances of various food constituents and may be used as a guide in nutritional practice in tropical countries.

TABLE XLIV

Standard Allowances

	Protein gm.	Ca gm.	P gm.	Vitamin A			Thiamine γ * / N.F.C.	Nicotinic acid mg.	Ascorbic acid mg.
				Preformed Int. Units	Alternative equivalent				
					Preformed Int. Units	Carotene Int. Units			
Adult	65	0·5	0·8	1,800	—	3,600	0·40	20	40
Adolescent 13–18	80	1·0	1·6	2,500	1,000	3,000	0·40	20	40
Child 8–12	70	0·75	1·2	2,500	1,000	3,000	0·35	15	35
Child 4–7	60	0·5	0·8	2,000	1,000	2,000	0·35	12	35
Child 1–3	30–50	0·5	0·8	1,800	1,000	1,600	0·35	10	30
Pregnant mother from 5th month	80	1·0	1·6	2,500	—	5,000	0·40	25	50
Lactating woman	85	1·0	1·6	2,500	—	5,000	0·45	25	50

* *Vide* p. 97.

The Correction of Deficient Diets

Three types of diets, which are in use among the labouring classes in different parts of the world, will be considered and the improvement of them discussed. The diets are in terms of man unit values.

Diet A is of a type in common use in many parts of Southern Asia. Table XLV gives the composition of Diet A together with a cheap but satisfactory diet of the same type.

TABLE XLV

DIET A

Foodstuffs		*Constituents*	
Highly milled raw rice	12 oz.	Calories	1,710
Millet	2 ,,	Protein	40 gm.
Pulse (dhal)	0·5 ,,	Fat	18 ,,
Dried fish	0·5 ,,	Carbohydrates	347 ,,
Vegetable fruits	2·0 ,,	Calcium	0·27 gm.
Sugar	1·0 ,,	Vitamin A	400 I.U.
(Various condiments)		Vitamin B_1	0·32 $\frac{\gamma}{\text{N.F.C.}}$
		Vitamin C	15 mg.
		Nicotinic acid	12 ,,

DIET A CORRECTED

Foodstuffs		*Constituents*	
Parboiled rice	12 oz.	Calories	2,700
Millet	4 ,,	Protein	78 gm.
Pulses	3 ,,	Fat	50 ,,
Dried fish	2 ,,	Carbohydrates	485 ,,
Roots (yams)	6 ,,	Calcium	0·55 gm.
Vegetable fruits	4 ,,	Vitamin A	3,500 I.U.
Vegetable leaves	2 ,,	Vitamin B_1	0·65 $\frac{\gamma}{\text{N.F.C.}}$
Sugar	1 ,,		
Coconut	4 ,,	Vitamin C	56 mg.
(Various condiments)		Nicotinic acid	20 ,,

Many of the labouring classes of Southern Asia live for various lengths of time on diets similar to Diet A, which is a semi-starvation diet.

Diet A is deficient in almost all constituents shown in the second column of Table XLV. Also it is deficient in riboflavin and probably in iron. It is curious that such a diet does not lead to frank signs of pellagra because theoretically there is an insufficiency of nicotinic acid.

Diet A becomes a typical beriberi-producing diet when the amount of highly milled raw rice is increased to furnish the calories needed by labourers.

Diet B is a type of diet in common use in many sea islands and along the coastal belts of continents within the tropics.

TABLE XLVI

DIET B

Foodstuffs		*Constituents*	
Bread (white)	10 oz.	Calories	1,900
Cassawa (grated and dried)	6 ,,	Protein	47 gm.
Roots (yams, etc.) or breadfruit	10 ,,	Fat	20 ,,
Fish (fresh)	4 ,,	Carbohydrates	383 ,,
Vegetable fruits	3 ,,	Calcium	0·70 gm.
Vegetable oil	1 ,,	Vitamin A	500 I.U.
Sugar	1 ,,	Vitamin B_1	0·45 $\frac{\gamma}{\text{N.F.C.}}$
(Tea and condiments)		Vitamin C	20 mg.
		Nicotinic acid	14 ,,

DIET B CORRECTED

Foodstuffs		*Constituents*	
Bread (white)	10 oz.	Calories	2,900
Cassawa (grated and dried)	4 ,,	Protein	96 gm.
Roots (yams, etc.) or breadfruit	16 ,,	Fat	32 ,,
Pulses (dried beans or peas)	3 ,,	Carbohydrates	·557 ,,
Fish (fresh)	6 ,,	Calcium	0·85 gm.
Vegetable leaves	2 ,,	Vitamin A	3,500 I.U.
Vegetable fruits	4 ,,	Vitamin B_1	0·60 $\frac{\gamma}{\text{N.F.C.}}$
Plantains	6 ,,	Vitamin C	70 mg.
Vegetable oil	1½ ,,	Nicotinic acid	22 ,,
Sugar	1 ,,		
(Tea and condiments)			

Diet B is deficient in calories, fat and vitamin A ; and protein, vitamin C, nicotinic acid and probably riboflavin are present in smaller quantities than is desirable. The vegetable oil is used for frying, and not more than about half is consumed. The diet as corrected is satisfactory with the exception that the fat in it is somewhat deficient, and the diet would be greatly improved by the inclusion of a fat of animal origin such as ghee.

Diet C is the type of diet which is in common use among the

poorer classes in some tropical and sub-tropical parts of the New World.

TABLE XLVII

DIET C

Foodstuffs		*Constituents*	
Yellow maize flour	16 oz.	Calories	3,000
Roots	8 ,,	Proteins	60 gm.
Fat pork	4 ,,	Fat	60 ,,
Milk	3 ,,	Carbohydrates	550 ,,
Vegetable fruits	2 ,,	Calcium	0·75 gm.
Molasses	4 ,,	Vitamin A	3,500 I.U.
Bananas	4 ,,	Vitamin B_1	0·46 $\frac{\gamma}{\text{N.F.C}}$
(Beverages and condiments)		Vitamin C	20 mg.
		Nicotinic acid	10 ,,

DIET C CORRECTED

Foodstuffs		*Constituents*	
Yellow maize flour	12 oz.	Calories	3,000
Roots	6 ,,	Protein	80 gm.
Fat pork	4 ,,	Fat	65 ,,
Bread (whole meal)	8 ,,	Carbohydrates	512 ,,
Pulses (gram, peanut, etc.)	3 ,,	Calcium	0·81 gm.
Milk	3 ,,	Vitamin A	6,000 I.U.
Vegetable leaves	2 ,,	Vitamin B_1	0·54 $\frac{\gamma}{\text{N.F.C.}}$
Vegetable fruits	4 ,,	Vitamin C	50 mg.
Molasses	2 ,,	Nicotinic acid	20 ,,
Bananas	2 ,,		
(Beverages and condiments)			

Diet C is deficient in nicotinic acid and riboflavin, and contains less vitamin C than is desirable. The consumption of such a diet is likely to lead to pellagra. Diet C is not easily corrected because where the available staple articles of diet are maize, fat pork and molasses, usually they cannot be replaced for economic reasons. In many countries beans are considered a necessary adjunct of pork ; and the same view may be taken of any kind of pulse. All pulses, however, are not rich in nicotinic acid, and the two with outstanding values of this vitamin are the peanut and the soya bean. Much of the pork used in some countries is fat pickled pork which may contain as much as 14 gm. of fat and only 3 gm. of protein per oz ; the two pulses mentioned above contain more fat than any other pulse, and a dish of fat pork and fat pulses is far from being appetizing.

Almost any pulse included in this diet will increase the amount of nicotinic acid, but not to as great an extent as is desirable.

The most reasonable solution is the replacement of some of the maize by a cereal far richer in nicotinic acid. Wholemeal bread will serve this purpose, but white bread, unless reinforced with nicotinic acid, is useless. Even as corrected the diet is not quite satisfactory, and could be markedly improved if lean meat and more milk is included in the diet.

Diet A, B and C as corrected need the addition of milk for children, pregnant and lactating women.

An example of a well-balanced diet suitable for hard work in a tropical climate is the " Field Scale of Rations for Indian Troops," given in Table XLVIII.

TABLE XLVIII

Field Scale of Rations for Indian Troops

	Amount oz.	Calories	Proteins gm.	Carbohydrates gm.	Fats gm.	Ca gm.	Iron gm.
Rice	10	970	20	216	3	0·05	9
Atta (wheat) . .	10	970	35	185	9	0·20	12
Dhal	3	294	18	50	2	0·15	3
Ghee	2	450	—	—	50	—	—
Meat with bone .	8	240	40	—	9	0·04	3
Milk, tinned . .	2	200	5	34	5	0·20	—
Onions . . .	2	24	—	5	—	0·08	—
Potatoes . . .	4	132	3	30	—	0·01	—
Vegetables . . .	4	53	3	12	—	0·04	4
Sugar	0·5	50	—	13	—	—	—
Tea, chillies, garlic, ginger, turmeric	$\frac{1}{6}$ each						
Salt	$\frac{1}{3}$						
Totals . .		3,383	125	546	73	0·77	31

An addition of 2 oz. each of rice and atta are allowed during cold weather.

CHAPTER XI

ANALYSES OF FOODSTUFFS

It is within the knowledge of everyone that unripe fruits are more acid and contain less sugar than those which are ripe ; that some carrots contain more fibrous matter than others ; that meat varies greatly in the amounts of fat and gristle ; and that the fish of one season are fatter than the same kind of fish of another season.

The quantities of the constituent of a vegetable product depend not only on the species but the variety of the plant, the stage of growth whether young or mature, the soil upon which they are grown and the circumstances of cultivation such as the past state of the weather determining the amount of moisture in the soil and also in the plants growing in it.

Two examples may be given to illustrate the variations in the constituents of foodstuffs.

(1) Table XLIX gives the analyses of some of the constituents in samples of the edible portion of the egg plant (brinjal) (Solanum melogena) as recorded from five tropical countries.

TABLE XLIX

Various Analyses of the Egg Plant (Brinjal)

	Protein per cent.	*Calcium* (*Ca*) per cent.	*Phosphorus* (*P*) per cent.	*Iron* mg. per cent.
Malaya . . .	2·2	0·014	0·015	0·68
Java	1·0	0·008	0·007	—
India . . .	1·3	0·024	0·064	1·31
Ceylon . . .	1·3	0·025	0·036	3·00
South America . .	1·2	0·011	0·023	0·61

(2) The ferruginous nature of a soil has a marked effect on the amount of iron in the vegetable products growing in it ; for example, one author has given the amount of iron in carrots as 9·0 mg. per cent. and another as 0·2 mg. per cent.

Although the quantities of fats, proteins and carbohydrates in

different samples of a plant product do not usually vary as greatly as the minerals, yet there are variations of these substances ; for instance, the protein in rice may range from 6 to 8 per cent. in different samples, and similarly the carbohydrates of sweet potato may vary from 24 to 32 per cent.

Several lessons are to be learned from the variations in the amounts of the constituents of vegetable products : firstly, mineral analyses should be carried out on samples of foodstuffs grown in various districts of a country because local deficiencies in the soils may cause a shortage of one or more minerals in the vegetable products ; secondly, tables recording analyses for general use in nutrition work can give only averages ; and thirdly, some margin of safety must be allowed in all prescriptions for diets.

The following tables, L to LXIII, give general averages of analyses which have been recorded of samples of foodstuffs grown in India, Malaya, Java, Ceylon, The Philippines, and of a few grown in South America. Some analyses have been taken from Dr. M. A. Bridge's well-known "Food and Beverage Analyses" ; and numerous other publications have been consulted.

The tables are a sufficient guide for nutrition work in most tropical countries, but may need corrections for some localities.

Each foodstuff is numbered in the tables and the numbers appear in three columns for the convenient following of the analyses across the columns.

The quantities of proteins, fats, carbohydrates, etc., are given in most cases in grammes per 100 gm. and in grammes per oz. The vitamins are given in terms of milligrammes or γ per oz. ; these figures can be converted to milligrammes or γ per 100 gm. by multiplying by 3·53.

No.	Common English name	Botanical name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Barley	Hordeum vulgare	11·0	12·0 3·4	1·5 0·4	71 20	1·5	4·0
2	Maize meal	Zea mays	11·5	9·0 2·5	1·5 0·4	75 21	1·5	2·5
3	Maize bread	Zea mays	44·0	6·0 1·7	5·0 1·4	44 12·4	0·8	—
4	Maize, tender cob	Zea mays	79·0	4·0 1·1	0·5 0·1	15 4·2	0·6	—
5	Millet, Great	Andropogon sorghum	12·0	10·0 2·8	2·0 0·6	70 20	2·0	4·0
6	†Millet, Italian	Setaria Italica	11·0	12·0 3·4	4·0 1·1	63 18	3·0	7·0
7	Millet, Pearl	Pennisetum typhoideum	12·0	11·0 3·1	4·0 1·1	70 19	2·5	1·5
8	†Millet, Indian	Panicum miliaceum	12·0	13·0 3·7	0·8 0·2	73 21	1·5	0·5
9	Millet, Little	Panicum miliare	11·5	8·0 2·3	4·5 1·3	64 18	4·5	7·5
10	†Millet, Koda	Paspalum scorbiculatum	13·0	8·0 2·3	1·0 0·3	76 21	1·5	0·5
11	†Millet (Ragi)	Eleusine coracana	13·0	8·0 2·3	1·3 0·3	72 20	3·0	3·0
12	Oatmeal	Avena sativa	10·0	14·0 3·9	7·0 2·0	64 18	1·8	3·5
13	Rice (home-pounded)	Oryza sativa	13·0	8·0 2·3	1·3 0·3	71 21	1·3	1·0
14	Rice (parboiled)	Oryza sativa	13·0	7·0 2·0	0·5 0·1	78 22	0·7	0·3
15	Rice (raw, highly milled)	Oryza sativa	13·0	7·0 2·0	0·5 0·1	78 22	0·5	—
16	Rye (meal)	Secale cereale	13·0	12·0 3·4	2·0 0·6	71 20	1·5	1·0
17	Wheat (wholemeal)	Triticum vulgare	13·0	13·0 3·7	1·7 0·5	70 20	1·5	1·2
18	Wheat flour (white)	Triticum vulgare	14·0	10·0 2·8	1·5 0·4	73 21	1·2	—
19	Wheat (wholemeal bread)	Triticum vulgare	40·0	9·0 2·6	2·0 0·6	48 15	1·0	0·8
20	Wheat (white bread)	Triticum vulgare	42·0	8·0 2·3	1·5 0·3	47 13	0·7	—
								Seeds and Flours
21	Adlay (Job's tears)	Coix lachryma	11·5	10·0 2·8	2·0 0·6	75 21	0·8	0·5
22	Buckwheat	Fagopyrum esculentum	11·0	10·0 2·8	2·0 0·6	66 18	2·5	8·5
23	Lotus seeds	Nymphœa nonchali	14·0	8·0 2·3	0·5 0·1	77 21	0·7	1·0

* The upper figure is grammes per cent. and the lower
† As prepared for cooking.
‡ International Unit = 3·3γ.

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	‡Thiamine γ per oz.	Riboflavin γ per oz.	Nicotinic acid mg. per oz.	Local name
1	342 / 97	0·04 / 0·01	0·35 / 0·10	1	110	15	1·0	
2	344 / 98	0·04 / 0·01	0·35 / 0·10	2	56	15	0·3	
3	245 / 70	0·05 / 0·01	0·10 / 0·03	3	50	—	—	
4	81 / 23	0·01 / 0·00	0·10 / 0·03	4	56	—	—	
5	338 / 96	0·02 / 0·00	0·28 / 0·08	5	70	—	0·4	
6	340 / 97	0·02 / 0·00	0·28 / 0·08	6	140	20	—	
7	338 / 96	0·02 / 0·00	0·28 / 0·08	7	100	20	—	
8	351 / 100	0·01 / 0·00	0·33 / 0·09	8	100	20	—	
9	328 / 93	0·02 / 0·00	0·36 / 0·10	9	100	20	—	
10	345 / 97	0·04 / 0·01	0·34 / 0·09	10	100	20	—	
11	332 / 94	0·38 / 0·10	0·35 / 0·10	11	100	20	—	
12	375 / 106	0·05 / 0·01	0·42 / 0·11	12	100	6	—	
13	348 / 99	0·02 / 0·00	0·20 / 0·05	13	80	28	1·4	
14	345 / 97	0·01 / 0·00	0·10 / 0·03	14	70	28	0·8	
15	345 / 97	0·01 / 0·00	0·10 / 0·03	15	15	11	0·4	
16	350 / 100	0·05 / 0·01	0·35 / 0·10	16	56	—	0·4	
17	347 / 98	0·05 / 0·01	0·35 / 0·10	17	100	33	1·2	
18	346 / 98	0·02 / 0·00	0·10 / 0·03	18	15	14	0·3	
19	246 / 70	0·04 / 0·01	0·25 / 0·07	19	100	28	0·8	
20	234 / 66	0·02 / 0·00	0·08 / 0·02	20	15	11	0·3	
not from Cereals								
21	358 / 100	0·02 / 0·00	0·20 / 0·06	21	50	—	—	
22	322 / 91	0·07 / 0·02	0·20 / 0·08	22	200	—	1·0	
23	344 / 97	—	—	23	—	—	—	

figure is grammes per oz., and similarly in other columns.

TABLE LI

No.	Common English name	Botanical name	Moisture per cent.	†Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Dhal (red) (lentil) .	Lens esculenta . .	12	24 / 7	0·8 / 0·2	61 / 17	2·2	—
2	Dhal (yellŏw) . .	Cajanus indicus . .	13	22 / 6·2	2·0 / 0·6	59 / 16	3·5	—
3	Field bean (dry) .	Dolichos lablab . .	10	24 / 7	0·7 / 0·2	60 / 17	3·0	2·0
4	Gram (black) . .	Phaseolus mungo .	11	24 / 7	0·8 / 0·2	55 / 15	3·2	4·5
5	Gram (cow) . . .	Vigna catiang . .	12	24 / 7	0·7 / 0·2	56 / 15	3·0	4·0
6	Gram (green) . .	Phaseolus aureus .	11	24 / 7	0·7 / 0·2	57 / 16	3·5	4·0
7	Gram (horse) . .	Dolichos biflorus .	12	22 / 6·2	0·6 / 0·2	56 / 15	3·5	5·5
8	Gram (rough) . .	Cicer arietinum . .	10	18 / 5·1	2·5 / 0·7	62 / 18	2·8	4·0
9	Gram (smooth) . .	Pisum sativum . .	14	20 / 5·6	0·8 / 0·2	58 / 16	3·2	4·0
10	Kidney beans (dried peas) (haricot) .	Phaseolus vulgarus .	14	24 / 7	2·0 / 0·6	45 / 12	3·0	3·0
11	Lathyrus pea (khesari)	Lathyrus sativus .	10	27 / 7·5	0·6 / 0·2	58 / 16	3·0	1·0
12	Lima bean . . .	Phaseolus lunatus .	12	19 / 54	1·0 / 0·3	59 / 16	3·5	5·0
13	Pea nut (ground pea)	Arachis hypogea .	8	27 / 7·5	40 / 11	20 / 5·6	2·0	3·0
14	Soya bean . . .	Glycine hispida . .	8	42 / 11	20 / 5·6	21 / 6	4·6	3·7

* Fresh beans and peas in table LIV, p. 190.
† The upper figure is grammes per cent. and the lower
‡ International Unit = 3·3γ.

*PULSES (DRIED)

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	‡Thiamine γ per oz.	Riboflavin γ per oz.	Nicotinic acid mg. per oz.	Local name
1	348 / 99	0·12 / 0·03	0·24 / 0·07	1	100	40	1·0	
2	342 / 97	0·14 / 0·04	0·25 / 0·07	2	100	50	1·0	
3	342 / 97	0·10 / 0·03	0·40 / 0·11	3	—	—	—	
4	323 / 90	0·20 / 0·05	0·37 / 0·10	4	110	60	0·7	
5	326 / 92	0·08 / 0·02	0·35 / 0·10	5	—	—	—	
6	331 / 93	0·13 / 0·03	0·26 / 0·07	6	100	75	0·7	
7	318 / 90	0·25 / 0·07	0·40 / 0·11	7	—	—	—	
8	343 / 97	0·18 / 0·05	0·24 / 0·07	8	75	75	1·4	
9	320 / 90	0·08 / 0·02	0·30 / 0·08	9	100	75	0·3	
10	294 / 83	0·14 / 0·04	0·56 / 0·15	10	—	—	—	
11	350 / 100	0·11 / 0·03	0·50 / 0·13	11	—	—	—	
12	321 / 92	—	—	12	—	—	—	
13	548 / 152	0·05 / 0·01	0·40 / 0·11	13	200	75	4·0	
14	432 / 125	0·25 / 0·07	0·70 / 0·20	14	100	60	1·4	

figure grammes per oz., and similarly in other columns.

TABLE LII

No.	Common English name	Botanical name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Arrowroot	Maranta arundinacea	13	0·2 / 0·0	0·1 / 0·0	86 / 24	0·2	0
2	Beetroot	Beta vulgaris	85	1·5 / 0·4	0·1 / 0·0	11 / 3	1·0	1·5
3	Carrots	Daucus carota	87	1·0 / 0·3	0·2 / 0·0	10 / 3	1·0	1·0
4	Cassava (dried)	Manihot utilissima	12	2·5 / 0·7	1·1 / 0·3	80 / 22	2·0	2·3
5	Leeks	Allium porrum	88	2·5 / 0·7	0·4 / 0·1	8 / 2	—	1·0
6	Manioc root	Manihot utilissima	62	1·0 / 0·3	0·5 / 0·1	35 / 10	0·8	1·0
7	Onion	Allium cepa	90	1·0 / 0·3	VL	9 / 3	0·3	—
8	Palmyra root (dried)	Borassus flabellifer	15	5·5 / 1·5	0·3 / 0·1	74 / 21	1·5	3·0
9	Parsnip	Pastinaca sativa	79	1·5 / 0·4	0·3 / 0·1	16 / 4	1·0	2·0
10	Potato	Solanum tuberosum	77	2·0 / 0·6	0·1 / 0·0	20 / 6	0·8	—
11	Radish (white)	Raphanus sativus	93	1·0 / 0·3	VL	4 / 1	0·5	1·5
12	Sweet potato	Ipomœa batatas	68	1·2 / 0·3	0·5 / 0·1	28 / 8	1·0	1·0
13	Turnip	Brassica rapa	87	1·3 / 0·4	0·2 / 0·0	7 / 2	1·0	3·0
14	Yam	Dioscorea alata	75	2·5 / 0·7	0·2 / 0·0	20 / 6	1·4	1·0
15	Aroid (Tania)	Xanthosoma	71	2·0 / 0·6	0·2 / 0·0	25 / 7	1·4	1·0
16	Yam (Taro)	Colocasia	67	2·4 / 0·7	0·2 / 0·0	28 / 8	1·2	1·0
17	Yam ("Elephant foot")	Amorphophyllus	80	1·2 / 0·3	0·1 / 0·0	18 / 5	1·0	1·0
18	Yam	Typhonium	70	1·5 / 0·4	0·1 / 0·0	27 / 8	1·5	—

* The upper figure is grammes per cent. and the lower
† International Unit = 3·3γ. VL = very little.

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	†Thiamine γ per oz.	Nicotinic acid mg. per oz.	Ascorbic acid mg. per oz.	Local name
1	348 / 99	0·01 / 0·00	0·02 / 0·00	1	0	0	0	
2	51 / 14	0·03 / 0·01	0·04 / 0·01	2	15	—	6	
3	46 / 12	0·04 / 0·01	0·04 / 0·01	3	12	—	3	
4	340 / 97	0·09 / 0·03	0·09 / 0·03	4	VL	—	VL	
5	44 / 12	0·05 / 0·01	0·07 / 0·02	5	5	0·1	3	
6	145 / 40	0·04 / 0·01	0·04 / 0·01	6	VL	—	VL	
7	40 / 11	0·15 / 0·04	0·05 / 0·01	7	5	0·1	3	
8	320 / 90	0·13 / 0·04	0·06 / 0·02	8	—	—	—	
9	72 / 20	0·05 / 0·01	0·04 / 0·01	9	—	—	2	
10	90 / 25	0·01 / 0·00	0·04 / 0·01	10	24	0·4	6	
11	20 / 6	0·05 / 0·01	0·04 / 0·01	11	12	—	4	
12	120 / 34	0·04 / 0·01	0·04 / 0·01	12	15	0·4	6	
13	33 / 9	0·07 / 0·02	0·05 / 0·01	13	12	—	7	
14	92 / 26	0·01 / 0·00	0·05 / 0·01	14	12	0·4	2	
15	108 / 30	0·04 / 0·01	0·14 / 0·04	15	12	0·3	1	
16	124 / 35	0·07 / 0·01	0·04 / 0·01	16	20	0·3	—	
17	80 / 22	0·05 / 0·01	0·02 / 0·01	17	5	—	VL	
18	116 / 32	0·06 / 0·01	0·02 / 0·01	18	10	—	VL	

figure is grammes per oz., and similarly in the other columns.

No.	Common English name	Botanical name	Moisture per cent.	§Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Alfalfa (lucerne)	Medicago sativa	84	4 / 1	0·4 / 0·1	5 / 1·4	2·3	3·5
2	(Alternanth)	Alternanthera sessilis	90	2·0 / 0·6	0·4 / 0·1	5 / 1·4	1·1	1·2
3	(Amaranth)	*Amaranthus gangeticus	84	4 / 1	0·4 / 0·1	6 / 1·7	3·0	—
4	(Basella)	†Basella rubra	91	1·0 / 0·3	0·4 / 0·1	5 / 1·4	1·4	1·2
5	Brussels sprouts	Brassica oleracea bullata	85	4·5 / 1·3	0·5 / 0·1	8 / 2	1·0	—
6	Cabbage	Brassica oleracea capitata	90	2·0 / 0·6	0·1 / 0·0	6 / 1·7	0·7	1·0
7	(Centella)	Centella asiatica	87	1·0 / 0·3	0·2 / 0·0	6 / 1·7	1·3	1·2
8	Coriander leaves	Coriandrum sativum	88	3·0 / 0·8	0·6 / 0·2	6 / 1·7	1·6	—
9	Curry leaves	Murraya kœnigii	66	6·0 / 1·7	1·0 / 0·3	16 / 5	4·0	6·0
10	Drumstick leaves	Moringa oleifera	75	6 / 1·7	1·5 / 0·4	13 / 4	2·3	1·0
11	Garden cress	Lepidium sativum	87	4·0 / 1·1	1·4 / 0·4	4·5 / 1·2	2·0	—
12	Gourd leaves	Lagenaria leucantha	87	3·0 / 0·8	0·7 / 0·2	3 / 1	2·4	4·0
13	(Ipomœa)	‡Ipomœa aquatica	91	2·0 / 0·6	0·5 / 0·1	4 / 1	1·3	1·3
14	Lettuce	Lactuca sativa	93	2·0 / 0·6	0·2 / 0·0	3 / 1	1·2	0·6
15	(Lusia)	Lusia spinosa	91	2·0 / 0·6	0·2 / 0·0	4 / 1	1·1	1·5
16	Mustard leaves	Brassica juncea	91	2·5 / 0·7	0·3 / 0·1	4 / 1	2·0	—
17	Neem	Azedirachta indica	59	7·0 / 2·0	1·0 / 0·3	23 / 6	3·4	6·1
18	Parsley	Petroselinum sativum	77	5·0 / 1·4	1·0 / 0·3	12 / 3	2·2	1·8
19	Radish leaves	Raphanus sativus	93	1·2 / 0·3	0·1 / 0·0	4 / 1	1·0	1·3
20	(Sesbania) (agathi)	Sesbania grandiflora	75	8·0 / 2·3	1·0 / 0·3	11 / 3	3·1	2·0
21	Spinach	Spinacia oleracea	92	2·0 / 0·6	0·4 / 0·1	4 / 1	1·5	1·5
22	(Talinum)	Talinum patens	92	1·0 / 0·3	0·2 / 0·0	4 / 1	1·4	1·0
23	(Trianthema)	Trianthema monogyna	91	1·5 / 0·4	0·2 / 0·0	5 / 1	1·4	1·5

* Other species are : A. spinosis ; A. viridis.
† Also B. cordifolia.
‡ Other species are : I. reptans, I. battata.
§ The upper figure is grammes per cent. and the lower
‖ International Unit = 3·3γ.

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	‖Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
1	40 11	0·50 0·14	0·10 0·03	1	3,000	10	40	
2	24 7	0·20 0·06	0·10 0·03	2	—	6	—	
3	47 13	0·50 0·14	0·10 0·03	3	2,000	10	50	
4	28 9	—	—	4	1,500	6	—	
5	54 15	0·04 0·01	0·08 0·02	5	60	35	20	
6	34 9	0·03 0·01	0·04 0·01	6	600	40	30	
7	30 9	0·40 0·10	0·07 0·01	7	—	—	—	
8	40 11	0·14 0·04	0·06 0·02	8	3,000	—	35	
9	97 27	0·80 0·23	0·06 0·01	9	3,000	—	2	
10	88 25	0·44 0·12	0·07 0·02	10	3,000	—	60	
11	46 13	0·36 0·10	0·11 0·03	11	—	30	—	
12	28 8	0·60 0·17	0·10 0·03	12	—	—	—	
13	28 8	0·10 0·03	0·05 0·01	13	1,000	15	35	
14	22 6	0·05 0·01	0·03 0·01	14	800	100	1	
15	26 7	0·13 0·04	0·05 0·01	15	—	—	—	
16	28 8	—	—	16	800	—	25	
17	129 37	0·12 0·03	0·19 0·05	17	1,500	—	—	
18	77 21	0·40 0·11	0·20 0·06	18	1,200	—	70	
19	24 7	0·20 0·06	0·03 0·01	19	—	—	—	
20	85 24	1·10 0·31	0·08 0·02	20	3,000	—	—	
21	28 8	0·06 0·01	0·01 0·00	21	120	30	14	
22	22 6	—	—	22	—	—	—	
23	28 8	0·08 0·02	0·04 0·01	23	—	—	—	

figure grammes per oz., and similarly in other columns.

TABLE LIV. VEGETABLE FRUITS,

No.	Common English name	Botanical name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Avocado pear	Persea america	74	2 / 0·6	17 / 4·8	5 / 1	1·0	1·0
2	Bamboo shoots	Bambusa arundinacea	87	4 / 1·1	0·1 / 0·0	7 / 2	1·4	—
3	Bread fruit	Artocarpus incisa	74	1·4 / 0·4	0·3 / 0·1	22 / 6	0·5	1·0
4	Broad beans (fresh)	Faba faba	72	8 / 2·2	0·6 / 0·2	14 / 4	1·0	4·0
5	Celery stalks	Apium graveolus	92	1·0 / 0·3	0·1 / 0·0	4 / 1	1·0	1·5
6	Drumsticks	Moringa oleifera	86	2·5 / 7	0·3 / 0·1	5 / 1	1·4	4·1
7	Egg plant (brinjal)	Solanum melongena	78	1·5 / 0·4	0·3 / 0·1	5 / 1	1·6	14·2
8	French beans (pods)	Phaseolus vulgarus	90	2·0 / 0·6	0·1 / 0·0	5 / 1	0·6	1·8
9	Jak fruit (pulp)	Artocarpus integrifolia	84	2·2 / 0·6	0·3 / 0·1	10 / 3	0·8	1·7
10	Jak fruit (seeds)	Artocarpus integrifolia	63	3·5 / 1·0	0·3 / 0·1	30 / 9	1·5	1·4
11	Ladies' fingers (Bandakka)	Hibiscus esculentus	90	2 / 0·6	0·2 / 0·0	7 / 2	0·8	1·3
12	Pea (fresh green)	Pisum sativum	73	7 / 2	0·5 / 0·1	15 / 4	1·5	2·0
13	Plantain (unripe)	Musa paradisiaca	84	1·0 / 0·3	0·1 / 0·0	14 / 4	0·7	0·5
14	Plantain flower	Musa paradisiaca	90	1·0 / 0·3	0·2 / 0·0	5 / 1	1·2	2·0
15	Tomatoes	Lycopersicum esculentum	94	1·3 / 0·4	0·1 / 0·0	4 / 1	1·0	—

* The upper figure is grammes per cent. and the lower
† International Unit = 3·3γ.

FRESH PULSES AND STALKS

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	†Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
1	181 / 51	0·05 / 0·01	0·05 / 0·01	1	—	—	—	
2	45 / 13	0·20 / 0·06	0·09 / 0·02	2	—	—	—	
3	96 / 27	0·04 / 0·01	0·04 / 0·01	3	4	—	—	
4	93 / 26	0·02 / 0·00	0·08 / 0·02	4	—	—	—	
5	21 / 6	0·03 / 0·01	0·04 / 0·01	5	—	—	2	
6	32 / 9	0·03 / 0·01	0·04 / 0·01	6	52	—	35	
7	32 / 9	0·10 / 0·03	0·10 / 0·03	7	6	15	3	
8	30 / 8	0·05 / 0·01	0·03 / 0·01	8	100	27	4	
9	52 / 15	0·03 / 0·01	0·02 / 0·00	9	100	—	—	
10	136 / 38	0·05 / 0·01	0·08 / 0·02	10	—	—	—	
11	38 / 10	0·09 / 0·03	0·06 / 0·02	11	18	20	5	
12	93 / 26	0·03 / 0·01	0·12 / 0·03	12	1,500	90	4	
13	62 / 17	0·02 / 0·00	0·04 / 0·01	13	15	15	7	
14	26 / 8	0·03 / 0·01	0·05 / 0·01	14	—	—	4	
15	24 / 7	0·02 / 0·00	0·04 / 0·01	15	100	35	8	

figure grammes per oz., and similarly in the other columns.

TABLE LV

No.	Common name	Botanical name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Ash gourd	Benicasa hispida	95	0·4 0·1	Tr.	3 1	0·3	0·7
2	Bitter gourd	Momordica charantia	94	1·4 0·4	0·1 0·0	3 1	1·2	0·8
3	Bitter gourd (small)	Momordica charantia	85	2·5 0·7	1·0 0·3	8 2	1·4	1·6
4	Calabash	Lagenaria vulgaris	95	0·3 0·1	Tr.	3 1	0·5	0·8
5	Cucumber	Cucumis sativis	95	0·3 0·1	Tr.	3 1	0·4	0·5
6	Pumpkin (red)	Cucurbita maximia	91	1·0 0·3	Tr.	6 1	0·6	1·0
7	Ridge gourd	Luffa acutangula	95	0·5 0·1	Tr.	3 1	0·3	0·0
8	Snake gourd	Trichosanthes anguina	95	0·5 0·1	Tr.	3 1	0·4	0·8
9	Vegetable marrow	Cucurbita pepo	96	0·3 0·1	Tr.	3 1	0·3	—

* The upper figure is grammes per cent. and the lower
† International Unit = 3·3γ.

TABLE LVI

No.	Common name	Botanical name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.	Fibre per cent.
1	Almond	Prunas amygdalis	5	21 6	56 15	14 4	3·0	2
2	Brazil nuts	Bertholletsia excelsa	5	17 5	67 18	7 2	3·0	1
3	Cashew nuts	Anacardium occidentale	6	20 5·5	47 13	23 6	2·5	1
4	Chestnuts	Castanea sativa	43	7 2	7 2	40 11	1·5	2
5	Coconut	Cocos nucifera	33	5 1·4	42 12	15 4	1·0	4
6	Coconut milk †	(Cocos nucifera)	—	3 1	35 10	10 3	0	0
7	Gingelly seeds	Sesamum indicum	5	18 5	43 12	25 7	5·2	3
8	Linseed (seeds)	Linum usitatissimum	7	20 5·5	37 10	28 8	2·5	5
9	Lotus seeds	Nymphœa nouchali	14	8·0 2·3	0·5 0·1	77 21	1·0	1
10	Mustard seeds	Brassica juncea	8	22 6	40 11	23 7	4·0	2
11	Pistachio nut	Pistacia vera	6	20 5·5	54 15	16 5	3·0	2
12	Rape seed	Brassica napus	6	19 5·4	40 11	25 7	4·0	6
13	Walnut	Juglans regia	5	17 5	65 18	11 3	2·0	3
14	Water chestnuts (flour)	Trapa bispinosa	4	8 2	1·0 0·3	78 30	5·0	4

* The upper figure is grammes per cent. and the lower
† This analysis is in terms of the coconut used to make
‡ International Unit = 3·3γ.

GOURDS AND PUMPKINS

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	†Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
1	15 4	0·02 0·00	0·02 0·00	1	Tr.	6	Tr.	
2	20 6	0·04 0·01	0·03 0·01	2	60	6	25	
3	50 4	0·00 0 01	0·15 0 04	3	60	6	25	
4	15 4	0·01 0·00	0·01 0·00	4	Tr.	—	—	
5	13 4	0·01 0·00	0·02 0·00	5	Tr.	8	2	
6	28 8	0·02 0·00	0·02 0·00	6	150	60	1	
7	15 4	0·03 0·01	0·04 0·01	7	20	7	20	
8	15 4	0·02 0·01	0·02 0·00	8	60	—	Tr.	
9	13 4	—	—	9	Tr.	—	6	

figure grammes per oz., and similarly in the other columns.
Tr=Trace.

NUTS AND SEEDS

No.	Calories per cent./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	‡Thiamine γ per oz.	Local name
1	634 180	0·23 0·06	0·46 0·13	1	Tr.	25	
2	699 198	0·18 0·05	0·59 0·16	2	—	—	
3	600 170	0·05 0·01	0·50 0·14	3	30	—	
4	240 68	0·08 0·01	0·10 0·03	4	30	—	
5	460 130	0·02 0·00	0·12 0·03	5	Tr.	4	
6	360 100	—	—	6	Tr.	3	
7	559 183	1·5 0·4	0·60 0·17	7	30	—	
8	525 148	0·17 0·05	0·37 0·10	8	15	—	
9	344 97	—	—	9	—	—	
10	540 153	0·48 0·13	0·70 0·20	10	80	—	
11	630 180	0·14 0·04	0·43 0·12	11	70	—	
12	536 151	—	—	12	—	—	
13	700 200	0·10 0·03	0·40 0·11	13	3	40	
14	352 100	—	—	14	—	—	

grammes per oz., and similarly for the other columns.
the milk (*vide* p. 228). Coconut water contains 6 per cent. sugar and total solids.
Tr.=Trace.

TABLE LVII. FRESH FRUITS OF LESS THAN 20 CALORIES PER OZ.

Common name	Botanical name	Moisture per cent.	Carbohydrate gm. per oz.	Calories per oz.	Vitamin A Int. Units per oz.	Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
*Apple	Malus malus	85	4	16	VL	40	3	
Apricot	Prunus armeniaca	84	4	16	600	—	3	
Cape gooseberry.	Physalis peruviana	83	3	12	1,000	—	15	
Cashew fruit	Anacardium occidentale.	88	3	12	—	—	170	
Grapes	Vitis vinifera	85	3	12	VL	VL	1	
Grape fruit	Citrus grandis	90	2	8	—	—	10	
Guava	Psidium guyava	84	3	12	60	—	40	
Hog plum	Spondias lutea	88	2	9	30	—	14	
Indian gooseberry.	Emblica officinalis	84	4	16	—	—	200	
Jambu fruit	Eugenia jambos	89	3	12	—	—	3	
Lemon juice	Citrus medica v. limonum.	85	3	12	5	—	15	
Lime juice	Citrus medica v. acida.	85	3	12	10	—	14	
Loquat	Eriobotyra japonica	87	3	12	—	—	1	
Mango (green)	Mangifera indica	90	3	12	50	—	4	
Mango (ripe)	Mangifera indica	86	4	16	1,200	—	11	
Mangosteen	Garcinia mangostana.	85	4	16	—	—	1	
Melon	Citrullus vulgaris	96	1	4	—	—	1	
Orange	Citrus auranticum	85	3	12	100	10	14	
Palmyra fruit	Borassus flabellifer	93	2	8	—	—	1	
Papaya	Carica papaya	90	3	12	600	—	15	
Peaches	Amygdalis persica	90	2	8	VL	—	1	
Pears	Pyrus communis	87	3	12	4	—	1	
Pineapple	Ananas sativis	87	3	12	15	—	5	
Plums	Prunus domestica	90	2	8	60	10	1	
Pomegranate	Punica granatum	80	4	16	0	—	5	
Rambutan	Nephelium lappaceum.	86	3	12	—	—	10	
Strawberry	Fragaris grandiflora	88	3	12	—	—	12	
Tree tomato	Cyphomaudra betacea.	83	3	12	150	—	1	

The percentages of protein, fats, calcium and phosphorus in the above fruits are very small.

* The skin of apples and some other fruits contains a far higher percentage of ascorbic acid than the flesh.

TABLE LVIII. FRESH FRUITS OF MORE THAN 20 CALORIES PER OZ.

Common name	Botanical name	Moisture per cent.	Carbohydrate gm. per oz.	Calories per oz.	Vitamin A Int. Units per oz.	Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
Bael fruit	Aegle marmelos	72	6	24	—	—	2	
Banana	Musa sapientum	61	10	40	30	10	1	
Banana (plantain).	Musa paradisiaca	77	8	32	40	10	2	
Bullock's heart	Anona reticulata	77	6	24	VL	—	2	
Custard apple	Anona squamosa	75	6	24	VL	—	2	
Durian	Duris zibethinus	60	10	40	6	—	7	
Figs	Ficus carica	81	5	20	80	—	1	
Passion fruit	Passiflora edulis	76	6	24	24	—	3	
Persimmon	Diospyros kaka	80	6	24	48	—	12	
Sour sop	Anona muricata	76	6	24	VL	—	2	
Wood apple	Feronia elephantum	70	5	24	—	—	1	

For bread fruit, jak fruit, unripe plantain, see Table LIV.

TABLE LIX. DRIED FRUITS

Common name	Botanical name	Moisture per cent.	Protein per oz.	Carbohydrate per oz.	Calories per oz.	Vitamin A Int. Units per oz.	Thiamine γ per oz.	Ascorbic acid mg. per oz.	Local name
Apricots	Prunus ameniaca	26	1·4	18	78	1,800	—	5	
Dates	Phœnix dactylifera	23	0·9	20	90	1,800	30	VL	
Figs	Ficus carica	18	1·1	21	95	1,000	—	2	
Peaches	Amygdalis persica	21	1·1	20	92	50	—	1	
Prunes	Prunus domestica	20	0·6	20	88	500	100	1	
Raisins	Vitis vinifera	18	0·6	22	92	VL	150	1	
Tamarind pulp.	Tamarindus indicus	21	0·9	19	82	100	—	3	

TABLE LX. CONDIMENTS AND SPICES

Common name	Botanical name	Essential oil per cent.	Other constituents	Local name
Asafœtida	Ferula narthex	3–7	Gum resins and sulphur compounds ($C_nH_{2n}S_2$)	
Caraway (Indian) omum	Carum copticum	4–6		
Cayenne pepper Chilli (capsicum)	Capsicum frutescens ,, annuum	Trace	Capsaicin ($C_{18}H_{28}NO_3$) is the active principle, also an oleo-resin (capsicin) and an alkaloid	
Cloves	Eugenia caryophyllata	15–20	Eugenol esters	
Coriander	Coriandrum sativum	0·8–1·0	(di-pinene)	
Cumin	Cuminum cyminum	2·5–4·0	Cuminic aldehyde (terpene)	
Fenugreek seeds	Trigonella fœnumgræcum	—	A fœtid bitter fatty oil, gum resins and saponin	
Garlic	Allium sativum	1	Allyl sulphides $(C_3H_5)_2S$	
Ginger	Zingiber officinale	0·5–3·0	Gingerin an oleo-resin	
Goraka	Garcina cambogia	—	Gum resin of bitter acid taste	
Mace	Myristica fragrans	4–10	(Macene)	
Mustard	Brassica juncea	3–4	(Allyl iso-thiocyanate C_3H_5NCS)	
Nutmeg	Myristica fragrans	3–7	Fatty oil about 30 per cent. of nut	
Pepper	Piper nigrum	1–2	Alkaloid piperine and a resin	
Pimento (allspice)	Pimenta officinalis	3–4	A resin and fatty oil	
Tamarind	Tamarindus indica	—	Tartaric and other organic acids	
Turmeric (Indian saffron)	Curcuma longa	3	A colouring matter and oleo-resin	
Vinegar	—	—	4–7 per cent. acetic acid	

No.	Common name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.
1	Beef (lean)	71	22 / 6·2	6 / 1·7	VL	1·0
2	Beef (fat)	63	16 / 4·5	20 / 5·5	VL	1·0
3	Chicken	66	27 / 7·6	5 / 1·4	VL	1·3
4	Crab	75	18 / 5	1 / 0·3	3 / 1	3·0
5	Duck (young)	61	18 / 5	19 / 5·3	VL	1·0
6	Egg (duck)	71	13 / 4	14 / 4	0·5 / 0·1	1·0
7	Egg (fowl)	75	13 / 4	11 / 3	VL	1·0
8	Egg yolk	49	16 / 4·5	33 / 9·3	VL	2·0
9	‡Fish (white lean)	77	20 / 5·5	1·0 / 0·3	VL	1·0
10	‡Fish (fat)	56	18 / 5	25·0 / 7·0	VL	1·0
11	Fish (dried sprats)	12	72 / 20	3 / 0·9	1·0 / 0·3	12·0
12	Fish (dried cuttle)	25	58 / 16	2 / 0·6	12 / 3	5·0
13	§Fish (salted and dried)	31	50 / 14	4 / 1	3 / 0·8	12·0
14	Goose (young)	47	16 / 4·5	36 / 10	VL	1·0
15	Ham	54	20 / 5·5	25 / 7	VL	1·0
16	Heart (bullock's)	71	22 / 6·2	6 / 1·7	VL	1·0
17	Kidney	71	22 / 6·2	6 / 1·7	VL	1·0
18	Liver	68	22 / 6·2	5 / 1·4	3	1·5
19	Lobster or Crayfish	79	18 / 5·1	0·10 / 0·03	0·5 / 0·1	1·0
20	Mutton	68	18 / 5·1	13 / 3·7	0·5 / 0·1	1·0
21	Oysters	88	6·2 / 1·7	1·2 / 0·3	3·7 / 1·0	1·8
22	Pork (lean)	75	19 / 3·3	5 / 1·4	VL	1·0
23	Prawns	79	20 / 5·5	0·3 / 0·1	VL	1·5

* The upper figure is grammes per cent. and the lower
† International Unit = 3·3γ.
‡ Most fish of tropical waters have 2 to 3 per cent. of fat.
§ The moisture varies from 20 to 50 per cent. for various

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	†Thiamine γ per oz.	Local name
1	140 40	0·01 0·00	0·19 0·05	1	17	30	
2	244 70	0·01 0·01	0·16 0·04	2	20	30	
3	153 43	0·01 0·00	0·20 0·05	3	15	30	
4	93 26	0·05 0·01	0·20 0·05	4	300	—	
5	245 69	0·01 0·00	0·20 0·05	5	20	—	
6	180 50	0·07 0·02	0·26 0·07	6	600	35	
7	152 43	0·06 0·02	0·22 0·06	7	620	35	
8	361 101	0·13 0·03	0·60 0·16	8	1,500	100	
9	89 25	0·03 0·01	0·16 0·04	9	20	15	
10	297 83	0·03 0·01	0·16 0·04	10	300	12	
11	320 92	2·00 0·57	1·80 0·50	11	200	60	
12	298 81	0·18 0·05	0·22 0·06	12	—	—	
13	247 70	0·18 0·05	0·22 0·06	13	50	12	
14	384 180	0·01 0·00	0·20 0·05	14	20	—	
15	305 86	0·01 0·00	0·20 0·05	15	15	80	
16	142 40	0·01 0·00	0·20 0·05	16	40	150	
17	142 40	0·01 0·00	0·20 0·05	17	40	200	
18	145 41	0·01 0·00	0·22 0·06	18	10,000	120	
19	81 23	0·03 0·01	0·20 0·05	19	20	15	
20	189 53	0·02 0·00	0·20 0·05	20	10	50	
21	50 14	0·05 0·01	0·18 0·05	21	100	—	
22	121 34	0·02 0·00	0·20 0·06	22	15	120	
23	84 24	0·08 0·02	0·20 0·06	23	20	—	

figure grammes per oz., and similarly in the other columns.
VL=very little.

samples, and the ash depends on the amount of added salt.

TABLE LXII

No.	Common English name	Moisture per cent.	*Protein per cent./per oz.	Fat per cent./per oz.	Carbohydrate per cent./per oz.	Ash per cent.
1	Butter	14	1·0 / 0·3	85 / 24	VL	VL
2	Butter-milk (skimmed)	90	3·0 / 0·8	0·3 / 0·1	5 / 1·4	0·8
3	Cheese (*vide* p. 248)	36	30 / 8·5	30 / 8·5	VL	4·0
4	Curds (*vide* p. 239)	90	3·0 / 0·8	3·0 / 0·8	2 / 0·6	0·8
5	Ghee	VL	VL	98	VL	VL
6	Milk (buffalo)	82	4·8 / 1·3	7·8 / 2·2	5 / 1·4	0·8
7	Milk (camel)	86	4·0 / 1·1	3·0 / 0·8	6 / 1·7	0·8
8	Milk (cow)	87	3·3 / 0·9	4·0 / 1·1	5 / 1·4	0·8
9	Milk (goat)	86	4·0 / 1·1	4·0 / 1·1	5 / 1·4	0·8
10	Milk (human)	88	1·6 / 0·4	3·7 / 1·0	7 / 2	0·2
11	Milk (mare)	90	2·0 / 0·6	1·2 / 0·3	6 / 1·7	0·5
12	Milk (condensed)	29	8 / 2·3	8 / 2·3	54 / 15	1·0
13	Milk powder (whole)	3	26 / 7·3	30 / 8	36 / 10	5·0
14	Milk powder (skim)	8	36 / 10	1·5 / 0·4	48 / 14	6·0
15	Milk powder (Borden)	—	16 / 4·5	10 / 3	72 / 20	—
16	Milk Powder (" Dryco ")	4	32 / 9	12 / 3·4	46 / 13	6·0
17	Milk Powder (Horlicks)	3	16 / 4·5	9 / 2·6	68 / 19	5·0
18	Milk Powder (" Klim ")	7	27 / 8	28 / 8	38 / 10	6·0
19	Milk Powder (" Lactogen ")	4	21 / 6	23 / 6·5	47 / 13	5·0

* The upper figure is grammes per cent. and the lower
† International Units = 3·3γ.

MILK AND MILK PRODUCTS

No.	Calories 100 gm./per oz.	Calcium (Ca) per cent./per oz.	Phosphorus (P) per cent./per oz.	No.	Vitamin A Int. Units per oz.	†Thiamine γ per oz.	Vitamin D Int. Units per oz.	Local name
1	770 218	—	—	1	2,000	—	10	
2	36 10	0·12 0·03	0·09 0·02	2	15	18	VL	
3	410 112	1·00 0·28	0·80 0·23	3	1,000	15	3	
4	47 13	0·12 0·03	0·09 0·02	4	15	18	1	
5	882 250	—	—	5	2,000	—	8	
6	100 28	0·20 0·06	0·12 0·03	6	50	20	1	
7	67 19	0·15 0·04	0·10 0·03	7	50	20	1	
8	68 19	0·12 0·03	0·09 0·02	8	50	20	1	
9	72 20	0·14 0·03	0·10 0·03	9	50	20	1	
10	66 18	0·03 0·01	0·01 0·00	10	50	20	1	
11	42 12	—	—	11	—	—	—	
12	320 90	0·30 0·08	0·22 0·06	12	100	40	2	
13	518 146	1·40 0·40	0·95 0·27	13	200	100	6	
14	448 124	1·50 0·42	1·00 0·29	14	60	100	VL	
15	442 123	0·75 0·20	0·50 0·14	15	—	—	—	
16	420 118	—	—	16	—	—	—	
17	412 116	0·35 0·10	0·26 0·07	17	—	—	—	
18	512 145	1·40 0·40	0·95 0·27	18	200	100	6	
19	479 135	1·20 0·35	0·85 0·23	19	150	80	5	

figure grammes per oz., and similarly in the other columns.
VL=very little.

TABLE LXIII. MISCELLANEOUS FOODSTUFFS

	Moisture per cent.	Fat per cent.	Carbohydrate per oz.	Calories per oz.	Vitamin A Int. Units per oz.
Honey	20	—	22	88	—
Jaggery	4	0·1	27	108	80
Jam * or marmalade	—	—	18	75	VL
Lard	—	100	—	250	VL
Liver oil (cod)	—	100	—	250	25,000–100,000
Liver oil (halibut)	—	100	—	250	5,000–7,000,000
Liver oil (various fish)	—	100	—	250	5,000–5,000,000
Mushrooms	90	VL	2	8	nil
Red-palm oil (*Elæis guineensis*)	—	100	—	250	10,000–15,000
Sago (Metroxylon sago)	12	—	25	100	nil
Sugar (white)	1	—	27	110	nil
Sugar (brown)	3	—	26	105	nil
Sugar-cane juice	90	—	3	10	nil
Toddy fermented	98	—	0·5	2	nil
Treacle (golden syrup)	20	—	22	90	—
Yeast (brewer's) (dried) †	10	2	12	80	VL
Yeast (baker's) (compressed) ‡	66	—	6	37	—

* Some jams retain the vitamin C of the fresh fruit.

† Has 40 per cent. or more of proteins, 2,000γ per oz. vitamin B_1, and 2 mg. per oz. riboflavin.

‡ Has 12 per cent. of proteins, 700γ per oz. vitamin B_1, and 2 mg. per oz. riboflavin.

Marmite (*vegex*), prepared from dried brewer's yeast, has 800γ per oz. vitamin B_1.

VL=very little.

CHAPTER XII

FOOD OF VEGETABLE ORIGIN

CEREALS

(For analyses see Table L, p. 182)

THE cereals are the seeds of grasses, most of which have been vastly improved by cultivation through the ages. They include wheat, rice, rye, maize, barley, oats and many millets. They are the staple articles of diet for the greater part of mankind; the exceptions are a few hunting peoples such as the Eskimos, a number of pastoral tribes of Asia and Africa living mainly on fermented milk and the inhabitants of a few sea islands who subsist mainly on yams and fish.

The proteins of average samples of cereals range from roughly 7 per cent. for rice to 14 per cent. for oats (but some "hard wheats" such as Hungarian and Russian spring wheat may contain as much as 20 per cent. of proteins). The carbohydrates range from about 65 to 78 per cent. and the fats from about $1\frac{1}{2}$ per cent. for rice to 8 per cent. for oats; mineral matter ranges from 1 to 3 per cent.

The whole grains of the cereals are moderately rich in the vitamins of the B complex; thiamine ranges from about 2 to 5γ per gm.; nicotinic acid is present in much larger amounts and ranges from 10 to 50γ per gm., maize has the lowest amount, and it has already been shown (p. 109) that this greatly limits the nutritional value of that cereal.

Most cereals are of no value as a source of vitamin A, but yellow maize and some of the millets contain a little carotene. Vitamin C does not occur in the dry grains in appreciable amounts.

The constituents of cereals are not evenly distributed throughout the grain. For nutritional purposes the grain may be considered to consist of three parts: (1) an outer coat, including the pericarp and aleuron layer; (2) the germ or embryo, occupying a small space at the lower end where the grain had been attached to the plant; (3) an inner part, the endosperm (Pl. VII, Fig. 13). There is

also a husk which is loosely attached in many grains and comes away during threshing, but in a few, such as barley and rice, the husk is firmly attached and can be removed only by pounding or the use of a hulling machine.

The richest part of the grain is the germ, but it constitutes only 1½ per cent. of the grain, next comes the pericarpal layers, and finally the endosperm is the poorest and the centre of it consists mainly of starch and a little protein. Table LXIII shows an analysis to the nearest whole figure of the three parts of a sample of rice.

TABLE LXIII

	Water	*Protein*	*Fat*	*Carbohydrates*	*Minerals*	*Cellulose*
Germ . . .	9	32	18	33	6	2
"Pericarp" . .	9	18	10	48	6	9
Endosperm . .	11	7	1	79	0·5	0·5

Wheat (*Triticum vulgare*)

Since the earliest known times wheat has been ground into a coarse flour for the making of leavened or unleavened bread, chappatis and various other preparations. It has been used as whole grains, and even up to recent times a dish of whole grains, called frumenty, was in use in Great Britain ; the wheat was soaked in water for about twelve hours, when the grains swell and burst, it was then boiled in milk, and among the upper classes was taken with fresh fruit or preserves. Frumenty is far from being an easily digested dish.

Nowadays, mills have become highly developed, and during the process of milling the grain is gradually reduced in size and the products from without inwards are, first, *the bran* of high cellulose content, next the *pollards*, *sharps* and *middlings*, and finally *the white household and baker's flours*, which come from the endosperm.

Prior to the war of 1939 the millers reduced the grains by about 30 per cent. before grinding them into white flours, which were called 70 *per cent. extraction flours*.

The *germs* of the grains, because they contain much fat, become balled or flattened particles during the process of milling, and these are easily sifted away from the flour or other products, preparations from the germs are called *offals*.

Bran is not a good foodstuff even for cattle, it is too rich in phosphorus and phytic acid and is poor in calcium, and when given as the main article of diet to horses leads to "Miller's horse's disease," a form of osteoporosis in which the bones become light and brittle. But the pollards, offals, etc., have far higher nutritional values in respect of proteins, vitamins and minerals than white flour and make excellent foodstuffs for domestic animals.

There are two main reasons why through the development of milling the most nutritious layers of the wheat grains have been discarded from human foodstuffs.

(1) *Whole meal flours do not keep as well as white flours*, especially during summer or in hot climates, the reasons are :

(*a*) Whole meal flours are more hygroscopic, due to a higher mineral content.

(*b*) There is a diastase in the germ which reduces starches to dextrin and sugar.

(*c*) Whole meal flours are richer in fats.

The above three factors favour the growth of moulds and bacteria, and this leads to mustiness and rancidity. Also insects such as the little flour beetles (*Tribolium*) breed readily in whole meal but cannot breed in white flour because it contains insufficient vitamins and minerals.

(2) *The coarser parts of the grain have been removed and the refined flour is more digestible than whole meal flour*, especially when in the form of bread in a good mixed diet. For many culinary purposes, such as in making pastries and fancy cakes, refined flours are essential.

Bread. When a preparation of yeast is kneaded into dough and the dough is kept in a warm place fermentation occurs, carbonic acid gas is given off and the dough swells and becomes a sponge having a network of innumerable gas-filled cavities ; and these are retained during baking. A good bread should be slightly elastic, of an even texture and without large cavities. Wheat is the only cereal from which a high-class bread can be made ; this is because the protein has a unique type of viscosity and when baked does not shrink.

At one time the yeast used in bread making was *brewer's yeast*,

but this has been largely replaced by a specially cultivated *baker's yeast* which imparts little or no flavour to the bread.

Many chemical methods of producing a spongy dough have been tried in bread making (aerated bread), but none have met with universal favour.

Wholemeal Bread versus White Bread. Much controversy has raged round this subject. The former is richer than the latter in several respects, as shown in Table LXIV.

TABLE LXIV

	Proteins per cent.	*Thiamin γ per gm.*	*Nicotinic acid mg. per 100 gm.*	*Minerals per cent.*
Wholemeal bread	9	4·0	3·0	1·7
White bread	8	0·5	0·6	1·0

Harriet Chick has shown that the proteins of flour from the whole grain (100 per cent. extraction) have distinctly greater biological value for growing rats than those of wartime "national wheatmeal" which is 85 per cent. extraction, and the proteins of this have a higher biological value than those of white flour of 75 per cent. extraction.

The explanation of her results is that the endosperm of wheat contains 11 per cent. of proteins, the bran 15 per cent. and the germ 40 per cent., and that gluten, which is the principal protein of the endosperm, is inadequate in certain essential amino-acids, and these are present in greater amounts in the outer layers and the germ of the wheat grain.

The above appears convincing in favour of breads of high extraction flours. But there is something to be said for the other side. Some of the calcium of wholemeal bread is not available because it is immobilized by the phytic acid most of which comes from the outer layers of the wheat grains. The digestibility of white flour is undoubtedly greater than flours of high extraction, especially for those who have been accustomed to the former.

The matter may be fairly summed up as follows: The digestive utilization of white bread in a good mixed diet is very high indeed, and it is of no importance if it is deficient in the vitamins of the B complex, so long as these are adequately supplied by other food-

stuffs, therefore the health of the well-to-do classes is unlikely to be affected by the use of white bread. On the other hand white bread will impair the health and lower the energies of the labouring classes when it enters very largely into their diets and is insufficiently fortified by protective foodstuffs.

Perhaps the best solution of the matter is being effected in America, where a "*standard loaf*" is being established, white flour is used and thiamine and nicotinic acid are added so that the bread contains them in the proportion in which they are present in the whole grain. Riboflavin would be a very desirable addition, but at present it is too expensive. In some localities, where the foodstuffs are deficient in calcium or very high in phosphorus, a calcium salt might be added to the bread.

Biscuits. Some are made entirely of white flour and water and are very hard. Army and ships' biscuits are examples of these. But most biscuits have various additions to the flour, such as milk, sugar, butter and flavouring agents.

Semolina is prepared from the central part of hard wheats, it is rich in gluten.

Macaroni, Vermicelli and similar Italian Foods are made from a paste of white wheat flour moulded in various ways or drawn into tubes, dried and lightly baked.

Rice (*Oryza Sativa*)

The main centres of production of this cereal are in Eastern and Southern Asia, and because of the teeming populations of these areas it may be that half the people of the world use rice as their staple cereal.

Whole rice contains about 8 per cent. of proteins ; this is lower than is the case with other whole cereals such as wheat, maize and millets. Rice proteins, however, have a high biological value even for those who are unaccustomed to a rice diet. The vitamins and minerals are concentrated mainly in the pericarp and germ, therefore the nutritive value of "raw" rice depends largely upon the amount of these remaining after the process of pounding and milling.

Home-pounded Rice (*Country Rice*). When this cereal is harvested and the grain is in the husk it is called *paddy*. The villagers of

Asia prepare their rice by pounding paddy ; this is done by placing it in a cavity hollowed out in a piece of stone or block of wood and pounding it with a heavy wooden pounder about 5 feet long and weighing about 7 lb. This removes the husk, the germ and a little of the pericarp and these are winnowed or sieved away. Thus prepared, rice retains a large proportion of its vitamins and minerals.

Milled Rice. With the spread of mechanization large numbers of engine-driven mills have been erected for milling rice. Pl. VIII,

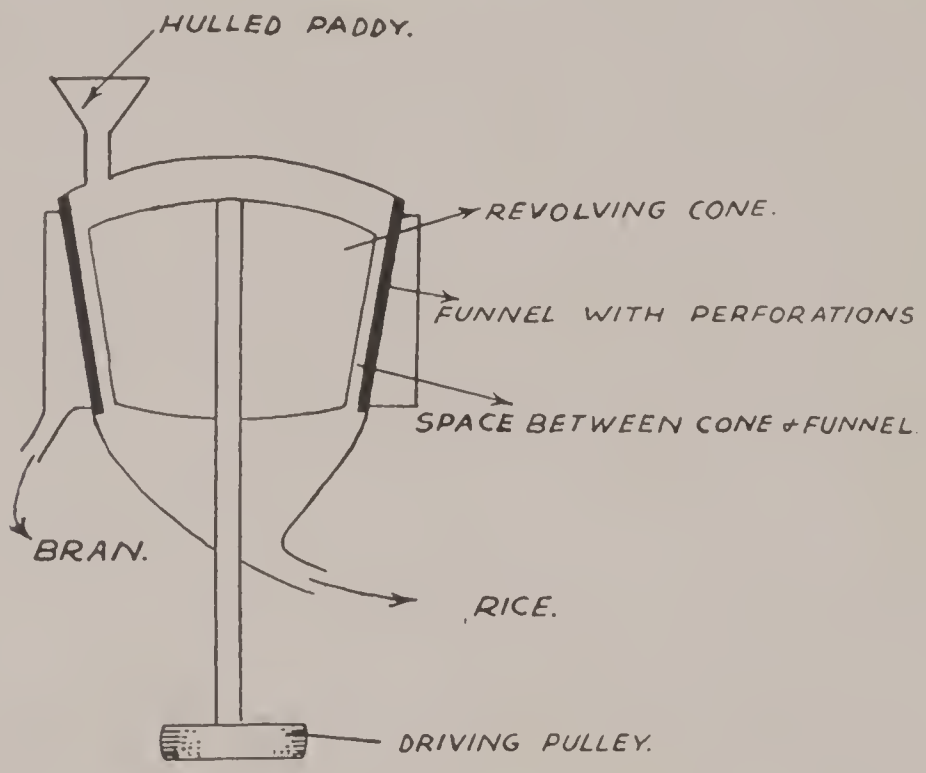


DIAGRAM OF RICE MILL.

FIG. 15.

Fig. 14 is a diagram of the lay-out of a large rice mill. The paddy is cleaned of foreign matter and passed to the hulling machine, where two stone discs are separated by about the width of the rice grain and the lower one revolves, and as the paddy passes between these the husk is cracked off ; next the husks and broken rice are winnowed or sifted away, and the rice passes to the first cone and funnel mill (Fig. 15), the cone is adjustable within the funnel and the clearance between the two determines the amount of pericarp which is removed ; the funnel is sieve-like with many perforations,

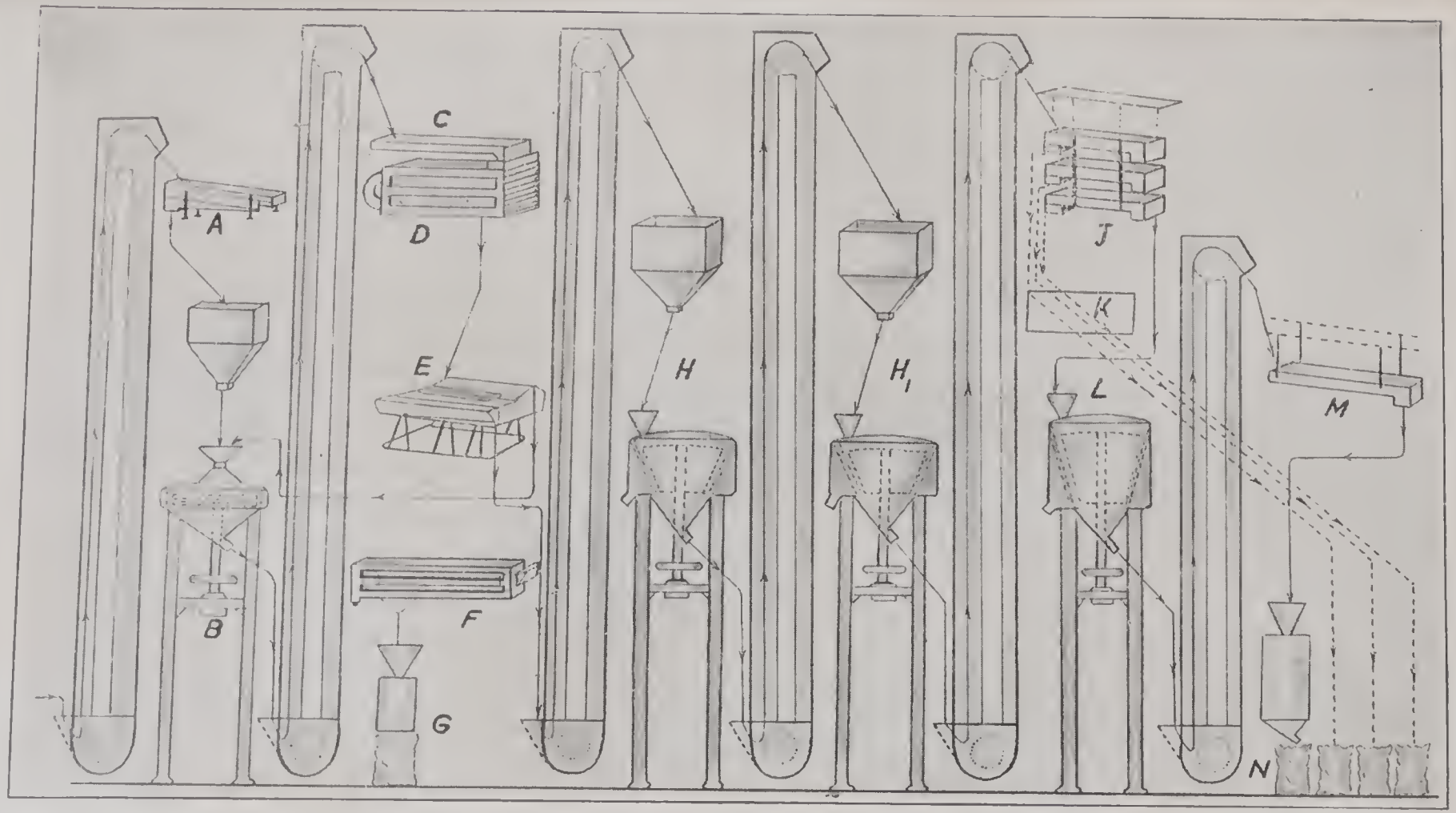


FIG. 14.

DIAGRAM OF RICE MILL

A. Shaking and aspirating to remove stones, mud, straw, dust, etc. B. Hulling by passing through space between two discs, one revolves. The product from the hulling machine consists of hulled grain (loonzain), small paddy, broken rice and husks. C. Broken rice removed by sifting. D. Husk removed by winnowing. E. Small paddy is shaken from the loonzain and returned to huller. F. Centrifugal bran machine. G. Bran packing machine. H. First cone mill. Lightly milled rice. H_1. Second cone mill. Moderately or highly milled rice. J. Rotary sieve to remove broken rice and bran. K. Bran grading plant. L. Polishing mill. M. Finishing shaker. N. Polished rice.

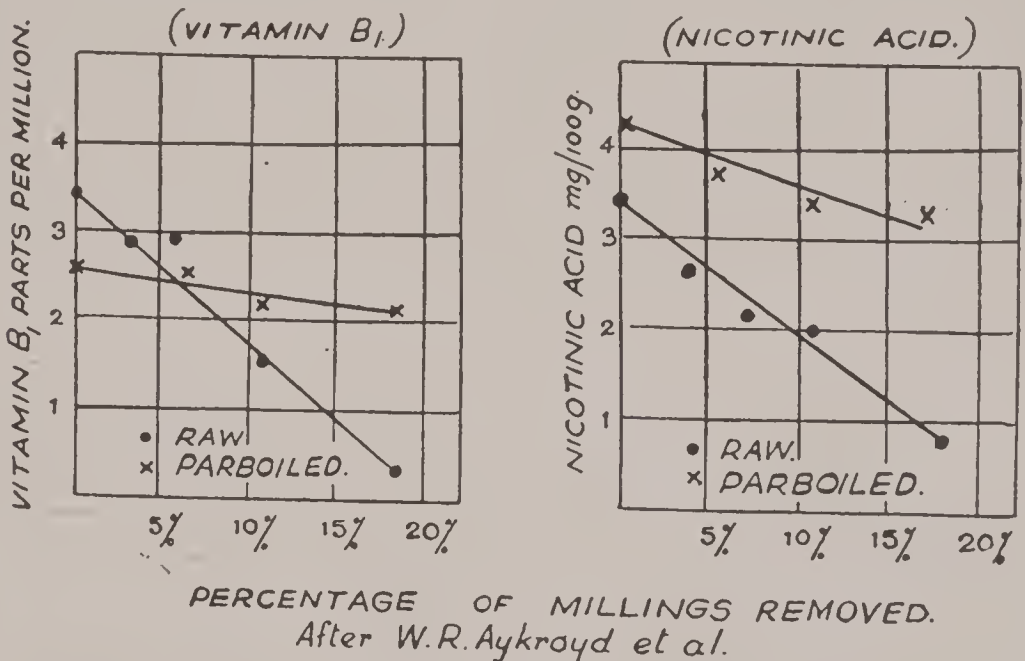
[To face page 208

and as the bran is removed from the grain it is forced through the perforations and thus conducted away from the grain.

There are two main types of milled rice :

(*a*) *Raw Rice.* In this case the paddy as it comes from the farmers is hulled and milled ; it is called " raw " because it is not boiled or steamed before milling. Although there are a vast number of different kinds of raw rice yet for nutritional purposes they fall into the categories : *lightly milled, moderately milled and highly milled* raw rice. The two latter must be condemned as dangerous staple articles of diet for the labouring classes, because the greater part of the vitamins have been removed with the bran. Highly milled raw rice cannot be recommended for the upper classes except in very small amounts because it is difficult to fortify adequately such a deficient foodstuff.

(*b*) *Parboiled Rice.* In this case the paddy is boiled or steamed.



GRAPH 3. Vitamins removed with rice-millings.

This " parboiling " distributes the vitamins throughout the grain and consequently smaller amounts are removed with the bran than is the case with milled raw rice. It is important that the amount of water used in " parboiling " should not be greater than can be taken up by the paddy, or some of the vitamins and minerals will be leached out into the excess water. Graph 3 shows the amounts

of vitamin B_1 and nicotinic acid removed from raw and parboiled rice during milling. As with raw rice there are many kinds of parboiled rice—milchards and muthusambas are the commonest kinds from the Burma rice mills.

Polished Rice. Milled rice is sometimes polished by being treated with oil or talc powder and passed through a cone and funnel mill (*vide* Pl. VIII, L) lined with goat's skin. This does not affect the vitamin value which has already been determined by the degree of milling. The glossy translucent rice sold in Europe and America is polished rice and also it has been highly milled, but this type of rice is not used by the labouring classes of Asia. Unfortunately the term *polished rice* has been frequently used in the literature when the authors were referring to *highly milled raw rice* as a potential cause of beriberi. The term *polished rice* should not be used in this respect as it leads to confusion.

Milled raw rice can usually be easily recognized, because it is dull white and opaque, whereas parboiled rice is greyish with a suggestion of yellow, and is slightly translucent. The pericarp of rice may be brown or greyish white, and with the former colour shreds of pericarp left upon the grain are easily seen and the degree of milling is indicated, but unfortunately the latter colour does not sufficiently demarcate the shreds of pericarp from the rest of the grain.

The P_2O_5 content of rice has been used as a guide to the thiamine content because the vitamin and the mineral are removed in much the same proportion during the milling of raw rice. The contracts for raw rice for the Indian army state that the content of P_2O_5 shall not be less than 0·4 per cent. The test, however, has very limited values and is not applicable to parboiled rice.

Washing and Cooking. Rice, as prepared by villagers, is usually dusty and contains inedible matter such as husks and bits of straw ; and as paddy is usually thrashed out on earthen floors, sand is transferred to the rice when the paddy is pounded ; rice which has been stored may contain weevils and other insects. Consequently rice must be washed before cooking. Most of the foreign matter is lighter than rice and can be easily floated away, and the sand falls to the bottom of the washing pot and the rice can be lifted from

it ; in some countries the floors of the pots are roughly grooved to trap the sand. Rice coming from up-to-date mills is cleaner and requires less washing.

Unfortunately a portion of the water-soluble vitamins is leached away when rice is washed, the amount depending on the length of time of washing. Most samples of rice can be washed satisfactorily in less than one minute, and this does not reduce the soluble vitamins by more than 20 per cent. ; but prolonged washing for five minutes or more may dissolve away 50 per cent. or more of these vitamins. Here again there is an advantage in the use of parboiled rice because vitamins are less readily leached from it.

As the water-soluble vitamins go so readily into solution when rice is washed, it is obvious that when rice is cooked in water for a quarter to one hour the vitamins will become evenly distributed between the rice and the water and therefore any discarded water will contain as much of these vitamins as an equal weight of the cooked rice. It is a common and good custom to add to the rice only that amount of water which can be absorbed by the grains swelling as they cook, so that when the rice is taken from the pot no water remains.

Therefore it is important that rice should be washed rapidly before cooking, and cooked with a minimum of water.

"*Steam*" *Cooking.* Cauldrons jacketed so that super-heated steam from a boiler can be circulated around them have been used in some tropical countries in Government institutions such as hospitals, asylums and jails. Rice and other foodstuffs may be cooked too rapidly at relatively high temperatures by this method ; and its introduction in some cases has been followed by a deterioration in the health of the inmates, and this has been accompanied by signs of various vitamin deficiencies. The method need not be condemned provided the valves of the boiler are adjusted so that the steam pressure is kept sufficiently low to prevent undue heating and destruction of food values.

Maize (Indian corn) (*Zea mays*)

Maize follows rice and wheat as the next most largely used cereal. It is of South American origin, and following the discovery of that

continent it has spread to many lands with sub-temperate climates, where it produces more heavily than in the tropics.

It is the staple cereal among the labouring classes of many parts of Mexico and the Southern States of the U.S.A. ; it has become widely used in the southern countries of Europe ; and is the main article of diet among the native races of large parts of Africa.

The protein of maize is not glutinous, and therefore it cannot be made into a leavened bread unless it is mixed with wheat flour ; indeed, being cheap it has been frequently used to adulterate wheat flour. The Africans use this cereal in the form of the meal, which is boiled with a limited amount of water into a firm mass ; from this lumps can be picked with the fingers, rolled into a neat bolus and thrown into the mouth. Maize meal is more suitable for this satisfactory method of feeding than most cereal meals. The commonest maize meal of the Southern States is *hominy*, other preparations are *cerealine* and *samp*.

Maize meal is the poorest of all staple cereals in nicotinic acid, hence the liability to pellagra (q.v.) of those who consume a diet consisting chiefly of maize meal.

Cornflour (*Maizena, oswego*) is prepared from maize flour by washing away the proteins and fats with alkaline solution until little except starch is left. A better name for it would be *corn starch* because this would prevent any confusion with maize flour or meal.

Corn flakes is a cooked preparation of maize flour which has been treated with malt honey, dried and rolled. It is a good breakfast cereal.

Millets

A large number of small grains belonging to diverse genera and even families are considered under this term. In North America and Britain they seldom appear in human dietaries and are only familiar to many people as small bird seed.

The following list gives nine species of millet and a few of their local names :

Great millet (*Sorghum vulgare*), dhurra, Kaffir corn, millo maize, American broom corn, jowar, cholam.

Pearl millet (*Pennisetum typhoideum*), bulrush millet, spiked millet, bajra, cambu.

Indian millet (*Panicum miliaceum*), common millet, panivaragu, meneri.

Italian millet (*Setaria Italica*), tanahal.

Koda millet (*Paspalum scorbiculatum*), varagu, amu.

South Indian millet (*Eleusine coracana*), ragi, kurrakhan, red millet.

Little millet (*Panicum miliare*), samai.

Sanwa millet (*Panicum frumentaceum*).

Japanese broom corn (*Panicum crus-galli*).

Italian millet is used by the labouring classes of Italy, and is the staple cereal among the negroes of some of the upper reaches of the Nile. Large quantities of millets are grown in China and India, and the yield per acre is far greater than with any other cereals. In the dry zones of India and Ceylon ragi is the predominant millet, and at certain seasons largely replaces the more preferred rice in the diets of the villagers.

The millets contain more cellulose than most of the larger-grained cereals and consequently they are not very digestible; and except as mixtures with other cereals they seldom appear in the diets of the well-to-do classes.

Most millets are poor in calcium and have nearly ten times as much phosphorus as calcium; ragi (*E. coracana*) is an exception, being rich in calcium.

The millets are prepared in various forms; ground into meal they are made into porridges, or into roasted flat discs (roti), or the hulled and crushed grain is used as groats.

Oats (*Avena sativa*)

Oats contain at least 14 per cent. of protein and up to 8 per cent. of fat, and in these respects is the most nutritious of the cereals. There are less satisfactory aspects of oatmeal, firstly it is difficult to separate completely the husk from the kernel, and there is $3\frac{1}{2}$ per cent. of indigestible cellulose in oatmeal, and secondly about 40 per cent. of the phosphorus is present in the form of phytin (inositol hexaphosphate), and this may render some of the calcium not

absorbable from the digestive tract. It is important that a foodstuff rich in available calcium should always be taken with oatmeal, and the best of these is milk. Therefore milk is a necessary adjunct of oatmeal porridge.

Oatmeal contains appreciable quantities of purine bodies, and experience suggests that these may aggravate miliaria (prickly heat).

Rye (*Secale cereale*)

Rye is used extensively in some parts of Germany and North-Eastern Europe for making bread, but its protein has not the elastic viscosity of the gluten of wheat, and consequently the bread is moist and dense. The coarser varieties of rye bread are referred to as *black bread* because of the dark colour ; this bread is far less digestible than wheaten bread and as much as 40 per cent. of the protein may be lost during digestion. *Ryvita* is a proprietary product prepared from crushed whole rye.

Barley (*Hordeum vulgare*)

At one time barley was the staple cereal of England, and it was during last century that it was finally replaced by wheat. *Pearl barley* is the whole grain hulled, milled and polished, and when it is ground to a flour it is called patent barley ; these are used to make a demulcent drink—barley water.

Flours made from Non-cereal Seeds

Buckwheat (*Fagopyrum esculentum*). This is a shrub of the family polygonaceæ, the fruit is dark brown with three-sided seeds in the kernel. The seeds are crushed into groats or ground into flour, and these preparations have much the same composition as similar preparations from cereals, and they are particularly rich in vitamin B_1, having about 8γ per gramme, but their cellulose content is very high. Buckwheat has nowhere become a main article of diet, but it is regularly issued to the Russian Army in the form of groats, and in the U.S.A. it is not an uncommon ingredient of cakes. The Hindus eat it on fast days because it is not a forbidden food. (*See Fagopyrism*, p. 311).

Adlay (*Coix lachryma jobi*). This is a shrub and the seeds are cone shaped, pearly hard and grey ; these seeds are perhaps most

familiar when they are drilled and used for necklaces for children. But in a few parts of the world, such as in the Philippines, they are ground into a flour and used to make cakes and other preparations.

Sago (*Metroxylon rumphii*) is obtained from the pith of the sago palm. The trees are split into sections and the starch washed out, dried and converted into pearl sago by granulating.

PULSES

(*For analyses see Table LI, p.* 184)

The beans and peas fall under the general term pulses. *Split peas* are called *dhals* in Southern India, and dried peas, especially the smaller kinds, are called *grams*.

The dried pulses are of very high nutritive value. They contain 20 per cent. or more of proteins, and because of this and their cheapness they have been called the "poor man's beef." The amount of fat varies greatly, some of them contain less than 1 per cent., but soya bean (*Glycine hispida*) has 20 per cent. of fats and the ground pea (*Arachis hypogæa*) is very rich indeed with about 40 per cent. The mineral matter is about 3 per cent. in most of them and they have good value in calcium ; the pulses in general are fairly rich in the vitamins of the B complex. The dhals and grams contain a fair amount of carotene, but not the dried beans, which are almost valueless in this respect. None of them contains more than very small quantities of ascorbic acid, but all quickly produce this vitamin when germinating (*vide* p. 126) and sprouted gram is a valuable foodstuff in countries where there are long dry seasons when fresh vegetables and fruits are difficult to obtain.

Unfortunately the pulses are not very digestible and do not find a prominent place in the diets of the well-to-do. But in countries where there are teeming populations and foodstuffs of animal origin, particularly milk, eggs and meat, cannot be produced in large amounts, the pulses must be used to fortify the proteins of rice or other staple cereal.

The grams are the most indigestible form of the pulses and they need prolonged soaking or boiling before they are sufficiently soft to be readily digested. In hard water the chief protein *legumin*

forms a tough compound with calcium, and a little soda may be added during soaking, but it should not be added to the water in which grams are boiled as the alkali will destroy some of the vitamins. The grams are often roasted and eaten as a snack between meals.

The Dhals

The commonest is the *lentil* (*Lens esculenta*), sometimes called *Massur dhal*. The split pea (*Cajanus indicus*) is also widely used, but there are several species which resemble the common split pea, and one of them—khesari (*Lathyrus sativus*)—cannot be recommended because under certain circumstances it is poisonous (*vide* Lathyrism, p. 297).

There are two methods of making dhal, the dry and the wet method. In both cases the peas are first graded by means of sieves, so that each grade contains peas of the same size. In the dry method the peas are thoroughly dried in the sun, and then passed several times through a splitting mill which consists of two stone discs one above the other, the clearance between the discs can be accurately regulated by raising or lowering the spindle on which the upper disc revolves. In the first passage through the mill the clearance between the two stones is slightly less than the diameter of the peas of the grade being split. This passage results in the cracking of the outer coats and the splitting of a small percentage of the peas; during preparation the product is called dol in India. Castor, gingelly or coconut oil is now stirred into the dol to the amount of about 1 per cent., and the dol is exposed to the sun, this helps to loosen the outer coats. The clearance between the stones is reduced and the dol passed a second time through the mill; this splits more of the seeds and oil is again kneaded into them and they are passed through the mill for a third time, and usually the process is repeated for a fourth time. Finally the dol is winnowed and sieved.

There are several variations of the wet method, but the principal in all is to swell the peas by soaking them in water, and then shrink them by drying in the sun, this has the effect of loosening the outer coats; they are then passed once or more through the mill, winnowed and sieved.

A good dhal should be easily and quickly reduced by boiling to a homogeneous soft mass containing no unbroken hard grains. The best dhals are prepared by the dry method.

The dhals are more digestible than the grams.

Pea flours are more digestible than the dhals and can be used either alone or mixed with cereal flours in soups, mashes, cakes, etc. The pea flours do not keep well under damp tropical conditions and soon become musty from bacterial and fungus growth and the attacks of insects. It is probable that the making of dhal originated in the need of pulses which would not rapidly deteriorate under the marketing conditions of the tropics, and would also be more digestible than the hard grams.

Beans

This refers to pulses with seeds more or less kidney shaped ; there is no other distinction from other pulses, indeed two of the commonest of them, the haricot bean (*Phaseolus vulgarus*) and the lima bean (*P. luneatus*) belong to the same genus as two of the grams. The dried beans are the least digestible of the pulses.

The lima bean contains a glycoside, linamarine, and an enzyme, linase, and these can react to produce prussic acid, but the amount of the poison produced varies with different strains of the bean, some produce only a trace but others as much as 60 mg. or more per 100 gm. (*vide* p. 392).

Fresh peas, beans and string beans (*vide* p. 226).

CHAPTER XIII

FOOD OF VEGETABLE ORIGIN (*continued*): ROOTS, VEGETABLES, NUTS AND FRUITS

ROOTS AND TUBERS

(*For analyses see Table LII, p.* 186)

THIS heading comprehends the foodstuffs which grow under or partly under the surface of the soil. The carrot and beetroot are examples of true roots, the tubers include for convenience all underground stems such as rhizomes, true tubers and corm; even bulbs fall into this category, such as onions, which consist of a number of scale leaves greatly swollen by the storage of starch.

Tubers which contain 20 per cent. or more of carbohydrates are major articles of diet in many parts of the world. They include the *potato*, *sweet potato*, *aroids*, *yams* and *manioc*. They come from a number of botanical families and very many genera. The following list comprises the majority of them.

"Tubers" having about 20 per cent. of Carbohydrates

Family.	*Genus.*	*Various local names*
Araceæ (Aroids)	Colocasia	Cocoyam, Tania.
	Alocasia	Taro, Dasheem.
	Xanthosoma	Edo, Kulkas, Koko.
	Caladium	Kiri-ala, Kond-ala.
	Amorphophallus	Kach-chi, Aroi.
	Typhonium	Elephant foot yam.
Convolvulaceæ	Ipomœa	Sweet potato, Kumara. Battata, Bathola.
Diascoraceæ	Dioscorea	Yams, Hingurala. Cush-cush, Nyambo.
Euphorbiaceæ	Manihot	Manioc "Tapioca." Cassava, Cassuda.
Marantaceæ	Maranta	Arrowroot (maranta).
	Calathea	
Menthaceæ (Labiatæ)	Coleus	Inala.
Solanaceæ	Solanum	Potato, Irish potato.

The Potato (*Solanum*) is of South American origin, and was introduced to Europe more than three hundred years ago, since then it has entered very largely into the diets of Europeans. Its nitrogen content indicates about 2 per cent. of proteins, but some of the nitrogen is in arginine and other substances which are not available for tissue building, probably the proteins available in the potato are not much more than 1 per cent. The potato has about 1 per cent. of minerals, the basic elements predominate, which is of value for maintaining the alkalinity of the blood. It is richer than many tubers in vitamin C, and although this vitamin gradually becomes less during storage yet there is always sufficient of it to make the potato a valuable anti-scorbitic when other fresh food is not available. When the potato was included in the diets of sailors in the days of the sailing ships, it greatly mitigated the effects of scurvy although it did not banish the disease.

Apart from the skin the potato has very little cellulose and is easily digested.

The Sweet Potato (*Ipomœa*). This was at one time in use in Great Britain and many parts of Europe; and except in the warmer parts of Europe has been completely replaced by the potato.

There are a very large number of varieties which differ from one another principally in two respects—the amounts of fibre and carotene which they contain. The extremes are shown by the yellowish variety which when cooked is mealy and easily chewed, and the white variety which when cooked has white dense and hard flesh; obviously the former is much the better product.

Yams and Aroids.[1] The word yam appears to come from the Portuguese word *inhame*, and *nama* is another variant of it. In the West Indies it is used entirely in reference to the tubers of the various species of the climbing genus *Dioscorea* (*vide* Fig. 16). In other parts of the world it is used in reference to almost any edible

[1] Native terms for birds, beasts or plants are often used very loosely except in obvious cases, such as, for a common crow, an elephant or a bread-fruit tree. A species of yam (or aroid) may be called by different names in the various localities of a country or the same name used for very different species. Where there is no dictionary of a particular language it is futile to discuss which name is correct, because all names are more or less correct until such time as those who produce the first dictionary arbitrarily settle the matter.

tuber such as those of the large-leaf *Araceæ* (*Colocasia*, etc.) (*vide* Fig. 16) and even for the manioc root.

The best of the dioscoreæ are as delectable and digestible and have much the same food values as a "flowery" potato. Some of the aroids such as the *taro* are fairly satisfactory, but others are fibrous and indigestible. The *tania* contains a sapotoxin, and

FIG. 16. Colacasia and Diascorea Yams

Dr. Alfred Clark [1] suggests that this may cause chronic nephritis in those who make this aroid a major article of diet.

Manioc (*Manihot utilissima*). This plant is the most prolific producer of tubers of any cultivated plant, as much as 16 tons may be grown to the acre in a single crop, an amount which contains more than 5 tons of starch. The roots contain less than 1 per cent. of proteins, and hence are of little value for growth or maintenance. They contain about 35 per cent. of starch and, as peeled for cooking, about 1 per cent. of fibrous matter. The roots are not rich in

[1] *Trans. Roy. Soc. Trop. Med. and Hyg.* (1932), XXVI, 301.

vitamins but contain appreciable amounts of A, B (complex) and C.

Manioc contains the glucoside *linamarine* and an enzyme *linase* which interact to form prussic acid (*vide* p. 302). The greater part of the glucoside is confined to the outer coats of the roots, and the fact that these are poisonous is well known to those who habitually use the root for food, and care is taken to peel and wash the root before it is cooked.

Manioc is used in several ways. It is taken as a boiled vegetable ; it is grated and dried in the sun and this coarse powder is called *farine* in the West Indies ; a common preparation is *tapioca*, which is the starch extracted from the root and dried in the sun. The term tapioca is used in India in reference to the whole root.

Carrots, Parsnips and Beetroot. The available proteins of these roots is not more than 1 per cent., and the carbohydrates about 10 per cent. They all contain vitamin C and carotene, the red carrot being particularly rich in the latter. These roots are too often boiled in excess of water and this dissolves some of the sugar, minerals and vitamins. There are many preparations in which their full values are retained, such as *purées*, curries, stewed and grated raw carrots and beetroot salads.

Turnips have only about 7 per cent. of carbohydrates, and many of them contain considerable amounts of fibrous tissue, therefore they are too bulky for the quantities of nutrients they contain.

Radish (*Raphanus sativus*). There are several varieties. The small radish of Europe has very little nutritive value, but it has a pungent flavour, due to allyl iso-thiocyanate, and is eaten as an appetiser or as a condiment with salids. The large radish of the tropics may weigh 1 lb. or more, and contains a fair amount of vitamin C and thiamine, and in general may be considered to have about the same nutritive value as the turnip. One species of radish (*R. caudatus*) is very rich in borates. Another species (in use in China and Japan) has very large seed pods, and these pods are taken with salads or as pickles in vinegar.

Onions (*Allium cepa*). There are many varieties of onion and they play a double part in diets—they have small nutritive values

and also act as condiments. The essential oils which they contain consist mainly of allyl compounds.

Arrowroot (*Maranta arundinaceæ*). This has a reputation as an invalid's food. The flour consists almost entirely of starch which has been prepared from the rhizome of the plant. The high cost of the flour is due to the great care which is taken to prevent taint ; it is handled with silver-plated shovels, packed into specially prepared casks and shipped as deck cargo to avoid any absorption of foul gases in the holds of ships. Starches can be prepared from manioc or maize meals which are far cheaper and have food values equal to arrowroot.

Palmyra Root (*Borassus flabellifer*). Flours are sometimes prepared from the roots of palms, the common palmyra palm of Ceylon and India is used for this purpose. The flour has little to recommend it, having low values in all necessary food factors except carbohydrates and calcium.

GREEN LEAVES

(*For analyses see Table LIII, p.* 188)

The herbivorous animals, because of the large capacity and the complexity of their stomachs, and the great length of their intestines, are able to consume enormous quantities of green leaves, and make full use of the small amounts of protein, carbohydrates and fat which they contain. But the capacity of the human stomach is small and the intestines are comparatively short, and therefore the amount of green leaves which can be eaten and digested is such as to add only trifling amounts of protein, carbohydrates and fat to the diet. Further, most green leaves contain much fibrous material which protects some of the nutrients from the digestive juices.

Very numerous green leaves are in use in the tropics (Fig. 17), and with few exceptions they are wild plants which have received no selective cultivation, and hence most of them are fibrous and coarse flavoured. In some countries the poorer classes make use of almost any green leaf provided it is not poisonous ; this is not strange when it is recalled that before the development of cottage gardens in Europe a similar use was made of wild leaves, and soups from such leaves as dandelions and nettles were in vogue.

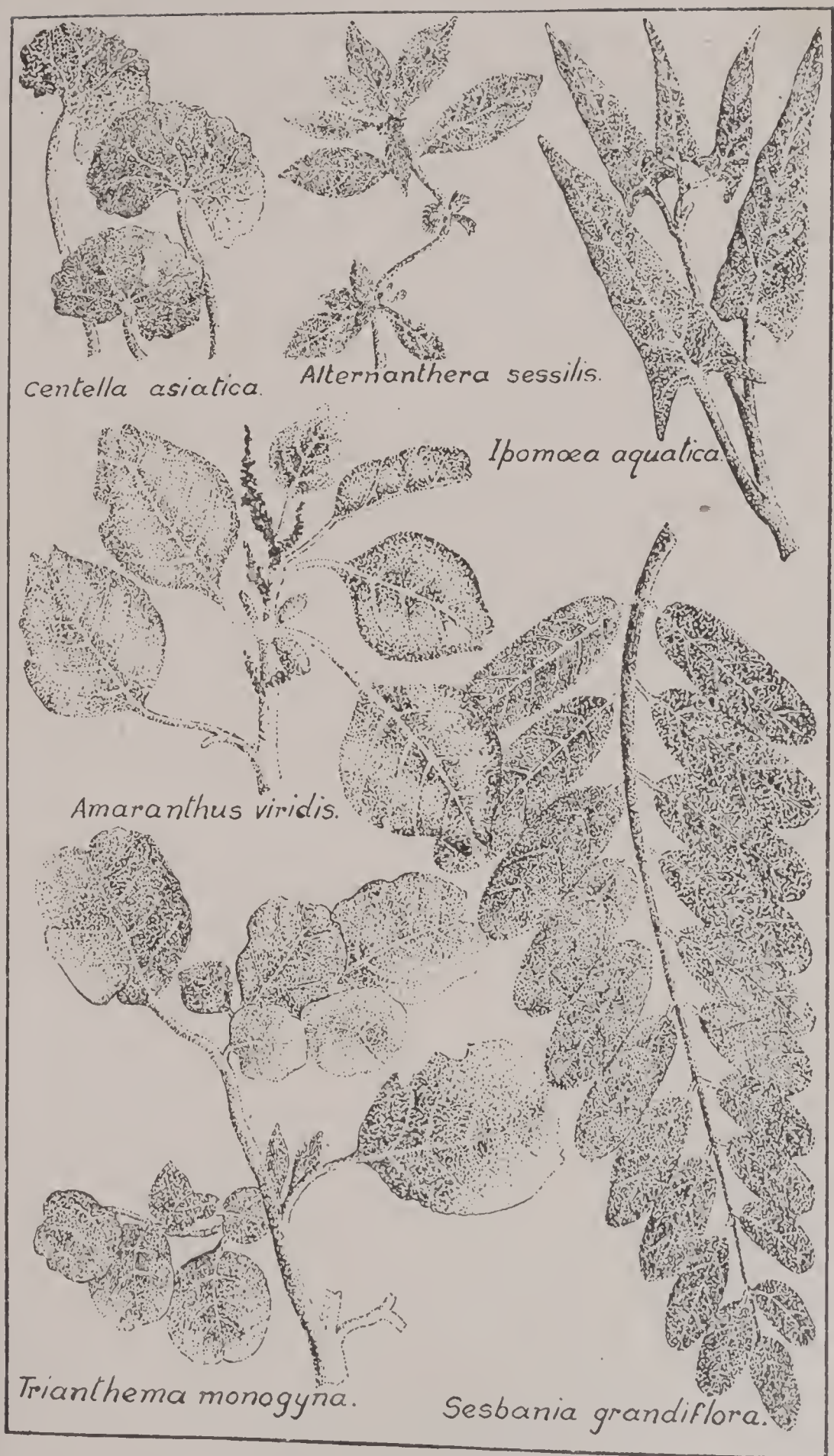


FIG. 17. Various edible leaves

The term " spinach " is used in several countries when referring to green leaves which on cooking resemble European spinach (*Spinacia oleracea*), the leaves of *Basella rubra* are an example of this.

In countries where there are long dry seasons, the leaves of shrubs and trees may be the only fresh food obtainable ; perhaps the most valuable of all of them is the drumstick tree (*Moringa oleifera*), which supplies both leaves and a long seed-bearing pod, and the greater part of the latter is edible.

Another example is " agathi " (*Sesbania grandiflora*), which has the reputation of being curative of " sore mouth," and this suggests that it may be rich in riboflavin.

All green leaves are rich in minerals and vitamins (especially carotene and ascorbic acid). They contain more carotene than any other vegetables with the possible exception of red carrots and tomatoes. In terms of dry matter they contain a greater amount of the vitamins of the B (complex) than most other foodstuffs, but in practicable dietetics they are too bulky to be rich sources of this group of vitamins.

The green leaves are fairly rich in calcium, but they also contain oxalates, and this probably renders some of the calcium unavailable, being in the form of the insoluble oxalate, but more knowledge is required on this matter.

VEGETABLE FRUITS, FRESH PULSES AND STALKS

(*For analyses see Table LIV, p.* 190)

Under this heading are grouped a heterogeneous collection of foodstuffs which are usually consumed as fresh vegetables.

Three fruits—*the jak fruit, bread fruit* and *unripe plantain*—have somewhat the same values as the starchy tubers. The jak fruit (*Artocarpus integrifolia*) grows from the trunk and larger boughs of the tree (Fig. 18) : two parts of the fruit are eaten—the pulp which is rich in carotene and the seeds which are very nutritious as they contain 4 per cent. proteins and 30 per cent. carbohydrates. The bread fruit (*Artocarpus incisa*) is very widely used in tropical islands, it grows from the ends of the smaller boughs of the tree ; it contains 22 per cent. carbohydrates and is a more satisfactory

foodstuff than the pulpy part of the jak fruit. The unripe plantain (banana) (*Musa paradisiaca*) is used in many countries as a boiled or roasted vegetable ; in the unripe stage of its growth the carbohydrates are in the form of starch and not sugars, the latter are formed as it ripens. " Banana or pisang flour " is made from the dried unripe fruit and is used in tropical America ; in some localities it is a staple article in the diets of labourers, it is usually well fortified

FIG. 18. Jak fruit and bread fruit trees

with salt meat or fish which corrects its poverty in proteins, and these with a few vegetables form a cheap and fairly well balanced diet.

Ladies' fingers, okra (*bandakka*) (*Hibiscus esculentus*) is a very common tropical vegetable. It is very mucilaginous when boiled, and some people object to this. It can, however, be cut up into segments and fried, when it loses much of its sliminess.

Egg plant (*aubergine, brinjal*). (*Solanum melongena*). The fruit of this plant are large smooth, white or purple pods when ripe. It

is one of the most popular tropical vegetables, although it has no outstanding values in vitamins or minerals.

Drumsticks (*Moringa oleifera*). These are the fruits of a tree of moderate size, which grows well in localities where there is a long dry season ; and before the break of the rains the leaves and long pods (drumsticks) of this tree may be the only vegetables procurable. It has high vitamin values.

French beans, string beans (*Phaseolus vulgatus*). There are many varieties of these beans, also there are several allied species or sub-species such as the *scarlet runner* (*P. multiforms*).

The pods and seeds have fair vitamin and mineral values.

Tomatoes (*Lycopersicum esculentum*). The plant is of South American origin and has been spread all over the world. The fruit has become a valuable addition to the diets of many tropical races. It is eaten both in the green and ripe condition. It has outstanding values in vitamins.

Fresh Peas and Beans. These do not grow well in the tropics except at high elevations in mountainous areas, and therefore seldom find a place in the diets of hot countries.

Avocado Pear. This is generally used as a vegetable although some people take it as a dessert fruit. Different varieties of it vary greatly in composition ; all are rich in fats, which range from 10 to 27 per cent., this gives the " pear " an oleaginous flavour.

GOURDS, PUMPKINS, ETC.

(*For analyses see Table LV, p.* 192)

These are the fruits of the cucurbitaceous plants. With the exception of the small bitter gourd (*momordica*) they contain more than 90 per cent. of water, and have practically no values for energy or repair. Four of them—*the calabash* (*Lagenaria*) (also called bottle gourd and water pumpkin), the ash or wax gourd, the cucumber and the vegetable marrow have very little food value of any kind, but are relished for their demulcent effects with hot curries, or in the case of cucumber as a pleasant addition to salads. Also these four are dear to the hearts of contractors selling vegetables to institutions, because they are cheap to grow, they keep moderately

well, " weigh heavily " and are convenient to handle ; but because of their poor food values they should be excluded from contracts for hospitals, prisons and other institutions.

The red pumpkin, the bitter, ridge and snake gourds have values in vitamins A, B and C.

NUTS AND OIL SEEDS

(*For analyses see Table LVI, p.* 192)

Nuts

The term is loosely used for a variety of fruits the shells of which are more or less hard. Sometimes the term " nut " is used in a sense which is not acceptable, the " pea nut " (*Arachis hypogea*) is an example of this, it is a pulse and has been considered with the other pulses (q.v.).

Most nuts are characterized by being very rich in proteins and fat, but not particularly rich in carbohydrates. Two outstanding exceptions to this are the edible chestnut and the water chestnut.

Chestnut (*Castanea sativa*). There are several species of edible chestnuts, all are rich in carbohydrates (about 40 per cent.) but contain only 6 and 8 per cent. of fats and proteins respectively. Chestnuts are the most digestible members of this group and have a greater general food value than any of them. They are the only " nuts " which have made any approach to being main articles of diet. Some of the peasantry of central France use them during the autumn and winter months as a principal foodstuff at two meals a day ; the nuts are shelled and steamed and taken with salt and milk.

The Water Chestnut (*Trapa*). This is a small aquatic plant ; the shell of the fruit has spines which point upwards and it has been called the *water caltrop*. The fruit is used at certain seasons in India and Ceylon where the shelled kernel is roasted and ground into a flour.

The Coconut (*Cocus nucifera*). This is the largest and most important of the tropical nuts. It consists of a husk of many layers of tough fibre and within this is the shell, forming a hard covering over the hollow kernel. and the cavity in the kernel contains a saccharine water (4 per cent. sugar). The tree is believed to have been indigenous in the East Indies, and to have been spread to other

parts of the world by ocean currents ; in support of this is the great buoyancy and resistence to long immersion in water of the fibrous husk and the predilection of the tree for growth near the sea and even on sea beaches.

However the dispersion of the coconut may have been brought about in the past, the trees now covering a vast acreage of land all over the tropical world were planted by the hand of man.

The weight of the whole nut after husking is about two and one-third times the weight of the kernel (*vide* Appendix XV, p. 355).

The composition of different kernels may vary considerably, depending on the degree of maturity of the nut, the soil on which the trees are growing, the season of the year and other factors. They contain 30–50 per cent. of moisture, 30–45 per cent. of oil, about 14 per cent. of carbohydrates and 4–5 per cent. of proteins. The content of indigestible fibre is high, being 3–4 per cent. Coconuts are valueless as a source of vitamins.

Coconut Oil is used for cooking by large numbers of Indians and other races of the Eastern tropics. The oil has a low iodine value of about 9, this means that it contains very little unsaturated fatty acids, such as linoleic, and this together with its lack of vitamin A value places it low in nutritive value among the vegetable oils.

Those who are unaccustomed to food cooked with coconut oil find the flavour somewhat objectionable.

Coconut Milk. This is the commonest preparation from the kernel. It must not be mistaken for the " saccharine water " which is present in coconuts and is sometimes used as a beverage. The milk is prepared by grating the fresh kernel and massaging and squeezing it into a little water ; it is economical to do this with the grated nut three times and then mix the three lots of extracts.

This emulsion has much the same appearance as cow's milk and contains about 70 per cent. of the solids of the grated coconut including 84 per cent. of the oil. The discarded refuse contains about 16 per cent. of the oil of the grated kernel and all the indigestible fibrous material (*vide* Table LVI, p. 192).

Therefore the preparation of coconut milk is a fairly satisfactory method of separating the digestible from the indigestible contents of the coconut.

Coconut milk is the basis of the curries of the East ; chillies and a selection from numerous condiments are seethed in it to form the spiced and aromatic fluids of the curries (*vide* p. 156).

The well-known "gula malaca" of the East consists of sago, palm syrup and coconut milk.

Coconut milk is sometimes prepared from desiccated coconut, 65 per cent. of the solids including 93 per cent. of the oil goes into the emulsion, thus it is richer in oil and poorer in emulsifying proteins and carbohydrates than the milk prepared from the fresh nuts ; this is a disadvantage as the oil tends to go out of emulsion in cooked preparations.

Grated coconut is used in various preparations. When it is mixed with lime juice, onions, garlic, chillies and other condiments the preparations are called *sambols*. These are used with curries or are taken to stimulate the appetite when the meal consists of one or other tasteless preparation of some cereal. Grated coconut is also used in various cakes and sweetmeats.

The Almond, Brazil, Cashew and Walnut are more or less typical in that they contain from 17 to 20 per cent. proteins and 42 to 65 per cent. of fat. They are not very digestible. But there are several fairly digestible flours in the market such as Fromm's extract, Nuttose and Malted Nuts, which have been prepared by roasting and grinding the nuts.

Oil Seeds contain 35–45 per cent. of fats, and edible oils are prepared from them. The two commonest are gingelly (sesame) oil (*Sesamum indicum*) and mustard (*Brassica juncea*) oil. Both contain some carotene and have fairly high iodine values (about 105). Mustard seeds are occasionally mixed with argemone seeds (*Argemone mexicana*), and this renders the oil poisonous, and probably epidemic dropsy is due to poisoning with argemone oil (*vide* p. 299).

FRUITS

(*For analyses see Tables LVII, LVIII and LIX, pp.* 194–195)

Fruits comprise a large number of comestibles of various food values. They may be considered under three headings :

(1) *Juicy Fruits* of less than 20 calories per oz. and most of them have good values in organic acids and vitamins.

(2) *Fresh Fruits* of more than 20 calories per oz. and having small values in organic acids and vitamins.

(3) *Dried Fruits* of substantial food values.

1. Juicy Fruits (Table LVII, p. 194)

Most of these are characterized by having good values in vitamin C, such as the citrus fruits and the guava. There are two fruits which greatly exceed the citrus fruits in the amount of vitamin C they contain, reaching as much as 130 mg. per oz., they are the Indian Gooseberry (*Emblica officinalis*) and the fruit of the cashew nut.

The mango, papaw, persimmon and other yellow fruits contain much carotene and have theoretical values in vitamin A up to 1,200 I.U. per oz.

The organic acids in fruits are of great importance, they consist of tartaric, citric, malic and other acids which are free or in combination with potash. These salts are oxidized in the body to carbonates, and this helps to maintain the alkalinity of the blood and reduce the acidity of the urine.

Some fruits such as cranberries, plums and prunes increase the acidity of the urine because they contain benzoic acid which remains an acid after absorption and is excreted as hippuric acid.

Experiments with rats have shown that citric acid and potassium citrate in the proportions present in orange juice increase the rate of growth and the retention of calcium; but there are other substances in fruit juices which have a similar effect, and this is one of many reasons why children should receive ample fruit in their diets.

Some fruits contain so much water that they have little value except as pleasing quenchers of thirst, an example is the water melon, which contains 96 per cent. of water.

2. Fresh Fruits of more than 20 Calories per oz. (Table LVIII)

The most important of these fruits are the two species and large number of varieties of the banana. The term plantain is used in some countries for all kinds of bananas whether ripe or unripe, in other countries the term is used only when referring to the unripe fruits used as a vegetable. A botanist might advocate a specific

difference and use the term banana for *M. sapienium* and plantain for *M. paradisiaca*.

The banana is a valuable addition to any type of diet as it is very digestible and has fair vitamin A and B_1 values.

In some countries a flour is prepared from the dried unripe fruit, it contains a little less than 5 per cent. of protein and about 84 per cent. of carbohydrates, and when this is used as a staple article of diet it must be reinforced by foodstuffs rich in protein (*vide* plantain, p. 225).

The "anonas" (custard apple, bullock heart and soursop) are common tropical fruits but their food values are not high.

Dried Fruits (Table LIX, p. 195)

Dates, apricots and prunes in the dried state contain from 2 to 5 per cent. of protein and about 70 per cent. of carbohydrates, mainly sugars. They are rich in carotene and fairly rich in vitamin B_1. Most of them have high iron values, dates being pre-eminent with 3 mg. per oz. Dates grown in the oases of the deserts of Asia and Africa are a staple article of diet among Arab tribes. The Bedouin who takes $\frac{1}{4}$ lb. of dates and a pint of camel's milk is making a meal of about 950 calories, well balanced except for some deficiency in vitamin C.

The Sugars of Fruits

Unripe fruits contain starches and sugars, but as the fruit matures the starches are changed to sugars and many ripe fruits are free from starch. All fruits contain glucose and fructose (*lævulose*); in some these sugars are in about equal proportions but in others one sugar preponderates. Saccharose is found in most fruits but not in all; pineapples, peaches, plums and melons are rich in this sugar.

Yeasts

Analysis and bioassays show that yeasts have outstanding dietary values, and it is probable that preparations of them will enter into many diets in the future. They can be grown in large quantities because they multiply rapidly in many saccharine media; and the

uncrystallizable sugars (molasses) from sugar factories and the saps tapped from palm trees form good pabula for their growth.

The consumable yeasts are of three kinds—brewer's, baker's and the wild yeasts—the latter are found in palm wines (toddy) and native beers. Yeasts vary considerably in the amounts of vitamins they contain. Most samples of brewer's yeast contain more thiamine than baker's yeast, but both have much the same values in other vitamins of the B complex. The wild yeasts have smaller values, and most samples have only about 30 per cent. of the vitamins of the cultivated yeasts. There is a little carotene in yeast, and a trace of ascorbic acid.

Marmite is a salted autolysed preparation of brewer's yeast and contains about 800γ of thiamine per oz.

The following gives the average amounts of vitamins in dried yeasts :

	Thiamine γ per oz.	Riboflavin mg. per oz.	Nicotinic acid mg. per oz.	Vitamin A I.U. per oz.	Ascorbic acid mg. per oz.
Dried brewers' yeast . .	600–10,000	2–4	10–25	50	0·5
Dried bakers' yeast . .	300–4,000	2–3	10–20	50	0·5

The proteins of yeast have high biological values.

Probably the best method of including yeasts in diets is in the form of dried powder added to soups or curries.

Liquid preparations of yeast do not keep unless they contain some preservative ; such a preparation, which has been found satisfactory for malnourished children, is given in Appendix VIII, p. 339.

CHAPTER XIV

FOOD OF ANIMAL ORIGIN

These may be considered under seven headings :

(1) Butcher's meat.
(2) Mammalian organs.
(3) Birds.
(4) Fish.
(5) Shell fish—Crustaceans, molluscs, etc.
(6) Milk and milk products.
(7) Eggs.

BUTCHER'S MEAT

(*For analyses see Table LXI, p.* 198)

Meat

Joints and cutlets of meat as purchased in the market consist of muscles and a variable amount of gristle and fat, depending on the part of the carcase from which the meat was cut, and on the age and condition of the animal.

The amount of fat in meat depends partly on the temperature in which the animal has been reared, the meat of cattle of the hot tropical lowlands is usually very lean, whereas that from the cooler highlands may have a fair amount of fat. Table LXVI gives the extremes in protein and fat of beef, mutton and pork.

TABLE LXVI

	Protein *gm. per oz.*	*Fat* *gm. per oz.*
Beef	5–8	1·5–8
Mutton or lamb	4–8	2–11
Pork	3–6	1–16

The digestibility of meat may be determined by the amount of connective tissue (gristle, etc.) and the quantity of fat among the muscle fibres ; thus pork is less digestible than beef or mutton, because fat among the muscle fibres delays the penetration of the digestive juices.

Ham and bacon are more digestible than pork apparently because the fat becomes granular and evenly distributed during the process of curing.

The meat of very fat animals, such as those of the Arctic climates or cattle fattened for the market, is not necessarily of low digestibility because most of the fat is deposited subcutaneously, and being separated from the muscle fibres does not protect them from the digestive juices.

The meat of old animals is tough because the connective tissues increase and harden with age. The meat of young animals is not necessarily more tender than that of older animals, for instance, veal is less digestible than prime beef because it contains an abundance of soft connective tissue which is not easily masticated.

When meat is cooked, whether by roasting or boiling, it shrinks and loses water to the extent of about one-fifth of its weight, hence, in equal quantities, cooked meat has more food value than raw meat. Moderate cooking improves the digestibility of meat, but overcooking impairs it.

Meat has fair values in vitamin B (complex) and small values in vitamin A and C.

MAMMALIAN ORGANS

Mammalian organs include the heart, liver, kidneys, sweetbread, brain and intestines.

The heart is somewhat denser in structure than skeletal muscles and therefore is less digestible, but it has a larger reserve store of vitamins.

Liver is very cellular with very little connective tissue, and therefore contains much nucleo-protein. Its great value is that it is richer in vitamins than any other flesh. Well-strained soups made from finely minced liver are of value for treating the malnourished in hospitals, even when they have bowel disorders.

Kidneys. These are cellular organs, and are particularly rich in vitamin B (complex).

Sweetbreads. The two most commonly used are the throat sweetbread or thymus of young animals, and the stomach sweetbread or pancreas ; they are the most digestible of all meats.

Brain. This consists largely of fatty material containing cholesterol and lecithin. It is quickly digested but badly absorbed; about 43 per cent. of the products of the brain tissue appear in the fæces. It is not a valuable food.

Intestines and Stomach are commonly called tripe. They are valuable foodstuffs easily digested and well absorbed.

BIRDS

The breast meat of birds, which spend most of their time upon the ground and not continually using their wings, is tender and digestible, far more so than the meat of the legs; these birds include chicken, turkey, pheasant, grouse and partridge. The reverse is the case with migratory birds which spend much time upon the wing, the snipe and woodock are examples of these.

The water birds, such as duck and goose, are very fat compared with most land birds; their flesh contains from 15 to 30 per cent. of fat and therefore is not very digestible.

FISH

Fish have been divided into two groups: the fat and the lean. This is a loose arbitrary division because fish vary greatly at different seasons in the amount of fat they contain. Most fish of tropical waters do not contain as much fat as fish caught in cold climates. The eel (17 per cent. fat), the salmon (12 per cent.) and even the herring (9 per cent.) are very fat compared with tropical marine fish. Some freshwater fish, occurring in dry zones, æstivate in small water holes, or even in dried mud when the main lake or stream has dried up, and these store up fat, which may reach 6–8 per cent. of the weight of the flesh just prior to the months of æstivation.

Sprats and Whitebait. Many small fish and the fry of many species of large fish are caught in large quantities in the seas and estuaries of the tropics. They contain 1–4 per cent. of fat and, what is more important, they supply a high percentage of calcium derived from the skeletal structures because the whole fish is con-

sumed. In some countries fresh or dried small fish are the most important source of calcium for growing children.

Fish, Salted and Dried. Large quantities of fish are salted and dried in the sun and are marketed far inland. Much salted fish caught in temperate climates is sold in the tropics, an example of this is the salted ling fish (*Urophycis*) caught off Canada, which is imported in large quantities into the West Indian Islands. This appears astonishing, for although the tropical seas contain far less fish than those of the temperate climates, yet the fish collect in large numbers around all the islands of the sea. The composition of fish salted and dried by local fishermen varies greatly, no two samples are the same in the amount of salt and moisture they contain, the salt varies from 4 to 15 per cent. or more and the moisture from about 8 to nearly 50 per cent. Consequently it is very difficult to estimate the approximate food value of any sample without analysis. The percentage of protein in dried fish varies from about $1\frac{1}{2}$ to 3 times the amount in the fish before it was dried. All dried fish, as found in the markets, have undergone somede composition, which is obvious from the odour ; yet most varieties seldom, if ever, give rise to gastro-intestinal disturbances in those who are accustomed to consume them.

Shell Fish

Vast heaps of shells, forming kitchen middens, have been left around the coasts of Europe by the populations of the later Stone Age. It appears that at some seasons in those times oysters, mussels, clams and other molluscs were almost the staple article of diet. Nowhere in the world are molluscs consumed to that extent at the present time.

Oysters may be taken as the type for molluscs, they contain 6 per cent. protein, 4 per cent. carbohydrates mainly in the form of glycogen in the liver and about $1\frac{1}{2}$ per cent. fat, therefore it follows that the food value of them is not high. In the raw state they are easily digested, but cooking renders them less digestible. They have good values in iron, iodine and particularly in copper.

Lobsters, Prawns and Crabs (*Crustaceans*) have much the same food values ; the edible flesh contains about 18 per cent. of

protein, but the muscle fibres are coarse and long and hence are not very digestible. The vitamin value is low. They are very widely used in the coastal areas of the tropics, and prawns, fresh or dried, are a valuable addition to many low protein diets of the East.

Crustaceans may be poisonous, either due to bacterial infection of the flesh after death, such as by organisms of the Salmonella group, or poisons accumulated in the flesh during life ; when the latter occurs it is usually seasonal and probably the poisons come from food taken by the crustaceans. The poisons of both these types give rise to gastro-enteritis. Many people, however, are immune, and in most cases it is probably an immunity acquired by past experiences with small doses of the poisons, but some people appear to have an inherent immunity of an undefined nature (*see* Chapter XVIII).

MILK AND MILK PRODUCTS

(*For analyses see Table LXII, p.* 200)

There are vast numbers of the labouring classes living on the lowlands of many countries who seldom obtain milk either for their children or themselves. Many tropical lowlands are extensively cultivated for various crops, but have few pastures suitable for cattle farming, and under these conditions the cattle are puny and the milk supply from them is small.

(Dr. M. Crawford studied the production of milk from a population of 241,274 cows in Ceylon and estimated that there would be available from them only 14 million gallons of milk yearly apart from the requirements of the calves. This means that there was not more than 1 oz. a day per head available for the human population of nearly 6 million.)

There are, however, many uplands or mountainous areas, where large stretches of grassland, variously called patna, savanna or veldt, are available for cattle farming ; and in these areas the size and strength of the children and adults contrasts favourably with the other inhabitants of the country who subsist on more or less vegetarian diets.

Composition of Milk

This varies with the species of animal producing it, the percentages of proteins and minerals are more or less proportional to the rate of growth of the newborn during the period of suckling (*vide* p. 38).

The cow is the main producer of milk for human consumption in most countries ; but considerable quantities of milk are obtained from other domestic animals in various parts of the world, in parts of Asia much milk comes from buffaloes, the goat is the principal source in some of the countries of the Mediterranean littoral, and in the desert and steppe countries of Africa and Asia both the camel and the mare contribute to the supply. Table LXVII compares the percentage composition of the milks of these species with human milk.

TABLE LXVII

Milk	*Proteins*	*Fats*	*Carbohydrates*	*Ash*
Human . . .	1·2	3·7	7	0·2
Mare . . .	2·0	1·2	6	0·4
Cow . . .	3·3	3·5	5	0·7
Camel . . .	4·0	3·0	6	0·8
Goat . . .	4·0	4·0	5	0·8
Buffalo . . .	4·8	7·8	5	0·8

The suckling receives no other food than milk until the time of weaning, but it does not follow that milk is a perfect food for growth, because, for some obscure reason, probably chemical, nature has failed to supply sufficient iron and vitamin C in milk for the needs of the growing suckling. But nature has corrected this failure by withdrawing quantities of these two necessities from the mother during the later months of gestation and placing them as reserves in the body of the developing young. The deficiencies of iron and vitamin C must be taken into account when dealing with any diet composed mainly of milk, whether for invalids or children.

Milk should be included in all diets, especially in those of children, because the proteins are of high biological value and are easily digested, and the fats are rich in vitamin A and D and contain the necessary unsaturated fatty acids (linoleic).

Milk, however, is an almost impossible staple article of diet for

a labourer, it is too bulky with too much protein, 1 gallon being needed to supply 3,000 calories and this contains 150 gm. of proteins, and it is deficient in carbohydrates necessary for hard work.

There are pastoral tribes who live almost exclusively on milk, their vast herds of cattle roam over large tracts of land. The Masai of Kenya are an example of these, they live on fermented milk and reinforce this with blood (they bleed all their cattle periodically) and also with various meats obtained from slaughtered animals. The men and women of the Masai are well grown and much bigger than the neighbouring agricultural tribes who are more or less vegetarian, yet the Masai never undertake strenuous work or prolonged activities probably because their diet is unsuitable for these, and they spend their lives lazily with spasmodic outbursts of social or pugnacious activities.

Fermented Milk

In warm climates where milk is used largely in the diets it is seldom, if ever, taken as fresh milk. There is much prejudice against fresh milk, and this is not unjustified where sanitary conditions are primitive. The organisms of dysentery, typhoid and other diseases grow rapidly in milk in warm climates, and milk once infected may in a few hours be so heavily charged with some pathogenic organism that it can lead to an overwhelming infection, such as fulminating bacillary dysentery in children. It is, however, a common and justified belief among the masses in some countries that curdled milk, which has been fermented for twenty-four hours or more, is safe, even when the product is somewhat malodorous.

The fermented milks of the Near East have special names and are well known. *Koumiss*, made with mare's milk, is the preparation of the steppes of Russia and Central and South-Western Asia, it contains a small percentage of alcohol. *Kephir* of the Caucasus is made from cow's milk, and is very similar to *Yoghourt* of Bulgaria and Turkey, *Matzoon* of Armenia and *Leben* of Egypt.

Three organisms are associated in these fermentations—a lactobacillus, a streptococcus (St. lactis) and a yeast. The actions of these may be exemplified from the case of *koumiss*, where the lactobacillus and streptococcus ferment the lactose with the production

of lactic acid and this curdles the milk ; the yeast produces a little alcohol ; and the organisms between them produce CO_2 and other gases and partly digest the proteins ; after about twenty-four hours considerable digestion of the caseinogen takes place and a sour thin effervesing fluid is produced, and this will keep almost indefinitely. The amount of alcohol is never more than 2 per cent., hence koumiss is not an intoxicating beverage.

Kephir from cow's milk differs from koumiss in two respects ; firstly, being made from cow's milk there is a greater amount of protein, hence larger curds ; and secondly, the curds contain grains of the three organisms growing in symbiosis in a tangled mass, these are called *Kephir grains*. Inoculation of each batch of milk is made with these grains after they have been broken up, hence the particular species are maintained in more or less pure culture.

Lében and Matzoon are very similar preparations. *Yoghourt* is supposed to be produced by a particular lactobacillus which has been named *L. bulgaricus*, but the evidence that streptococci and yeast do not play a part in the fermentation is inconclusive. *L. bulgaricus* has been much used in Great Britain and America for preparing sour milk, and at one time it was believed that the lactobacillus became established in the intestines of those who drank sour milk, and there maintained a lactic acid fermentation, which checked the growth of other and less desirable organisms. This view is now known to be incorrect and sour milk is less fashionable than it was.

In some places the milk is fermented after it has been skimmed, this may prevent an undesirable production from the cream of butyric and other stomach-irritating fatty acids.

In most parts of the tropics preparations similar to those already mentioned are in use. The sour milk of the Masai is one example—the cows are milked into long gourds, which contain the remnants of the previous batch of sour milk, the fresh milk is shaken up and thus receives a heavy inoculation of the organisms ; lactic acid production soon curdles the milk ; the gourds are frequently shaken and this produces a preparation in which the curds are small and granular.

In India and Ceylon both buffaloes' and cows' milk are used, and

in some localities the former is preferred; here again the same three organisms are found in the curds—namely, a lactobacillus, streptococcus and a yeast. The methods of preparation is to boil the milk, allow it to cool, and then stir in a piece of curd from a previous preparation. The curds are not eaten until after forty-eight hours of fermentation and in some places curds of three days are preferred.

Table LXVIII gives the average activity, reckoned as lactic acid, of several samples tested at intervals of eight hours' fermentation.

TABLE LXVIII [1]

Hours of fermentation	*Acidity estimated as lactic acid*
8	0·41
16	0·92
24	1·32
32	1·43
48	1·75

The sterilizing power of fermented milk on pathogenic organisms has been tested. In one series of experiments [1] it was found that when B. dysenteriæ, V. choleræ or B. typhosus was inoculated respectively to the amount of one part of twenty-four hours broth culture to twenty-nine parts of different batches of curds containing 1 per cent. lactic acid, the organism rapidly died out and could not be isolated after three hours. Such a heavy infection as this does not occur naturally and it may be concluded that fermented milk is not likely to be a source of infection.

The food value of curds may be compared with that of milk—firstly, about two-thirds of the milk sugar is broken up, fermentation ceases before it is all destroyed because of the accumulation of lactic acid; secondly, fatty acids are produced in small amounts, and these include butyric acid; and thirdly, in some fermented milks about 7 per cent. of the proteins are broken up. Thus there is less carbohydrate in curds than in milk, the proteins are more easily digested, but the fatty acids are undesirable irritants. Curds cannot be considered a first-rate staple article of diet, but as a supplement to more or less vegetarian diets they are excellent, especially for

[1] *Cey. J. Sci.*, V, 17.

children after they have become accustomed to them. Although curds are inferior to fresh milk for weaning infants, yet that they can be used for this purpose is amply testified by the practice of the Masai and other tribes who slowly wean their children to them, whilst still being partly fed at the mother's breast.

In many tropical countries buffaloes thrive where cows will not, and more use should be made of buffalo milk. It has a pleasant taste, and when properly diluted, infants can be satisfactorily weaned upon it.

Preserved Milks, included Condensed, or Powdered Milk in Tins, Cans or Bottles

Much imported preserved milk is used in many tropical countries, and in some places its use is very high indeed relative to the economic status of the masses. Milk preserved in tins or bottles has several advantages over fresh milk—it is more easily distributed, safer and more convenient for household use.

With improved methods of preparation and the addition of vitamins, these milks are likely to be sold in greater quantities in the future.

The preparation of preserved milk on the market fall into six categories :

(1) Unsweetened condensed milk (evaporated).
(2) Sweetened condensed milk.
(3) Condensed skim milk.
(4) Whole milk powders.
(5) Skimmed milk powders.
(6) Milk powders with the addition of sugar, barley, malt, etc.

(1) *Unsweetened Condensed Milk* (*Evaporated*). There are many brands of this milk, and among these are : Ideal, First Swiss, Viking, Hollandia and Carnation. They are prepared by evaporating milk under reduced pressure to one-third of its volume. The approximate average composition of them is :

Total solids	*Protein*	*Fat*	*Milk sugar*
25	7	8	12

When they are diluted to the extent of two parts of water to one of the milk, they have about the same value as a good sample of cow's milk except that in most cases there is a reduction in the vitamin

content. Infants weaned on condensed milk must be given fish-liver oil and fruit juices.

Unsweetened condensed milk has limited uses in the tropics because when the tin is opened it must soon be used or it will go bad.

(2) *Sweetened Condensed Whole Milk.* This is a favourite form of milk for adults of the not well-to-do classes. The milk is prepared by evaporating it to about one quarter of its original volume and adding 35–40 per cent. cane sugar. Among the best brands are : Nestle, Rose, Milkmaid, Anglo-Swiss, Lion, and Eagle Brand.

The approximate average composition is :

Total solids	*Protein*	*Fat*	*Milk sugar*	*Cane sugar*
71	8	9	16	38

If as much water is added as was originally evaporated the mixture is too sweet for the taste of most people ; and the degree of dilution recommended on the tins produces a sweet milk considerably lower in protein and fat values than cow's milk.

Many brands have been sold on the market which contain a little milk (or skim milk) and much packing such as starch and sugar, and any brand which is sold well below the price of a good-class brand, such as Nestle's, should be viewed with suspicion. But all imports of condensed milk should be controlled by frequent analyses of samples.

Sweetened condensed milk is not generally suitable for infants because it contains too much sugar, but some infants who digest fresh cow's milk badly will thrive for a time on condensed milk.

Sweetened condensed milk will keep for a day or two after the tin is opened. But it will not keep indefinitely because some fungi and bacteria can slowly establish a growth on the milk.

(3) *Condensed Skimmed Milk.* This is a cheap and unsatisfactory preparation. If tinned skimmed milk is required the powder is the only acceptable form.

(4) *Whole Milk Powder.* There are two general methods of preparing this. In one case the milk is sprayed into a low-pressure chamber where the water is sucked off as steam and the powder falls to the bottom ; in the other case a film of milk passes over hot rollers and is rapidly scraped off as a powder. Cow and Gate Milk is an example of the latter method. The " roller " process

is the better as the amounts of vitamins are not markedly reduced, except vitamin C.

The approximate average composition of desiccated milk powder is :

Protein	*Fat*	*Carbohydrate*	*Ash*
26	30	36	5

Seven parts of water added to one part of the powder renders it about equal to fresh cow's milk.

Among the brands of whole milk powders are : Glaxo Full Cream Dried Milk, Cow and Gate (Fullcream), Trufood, Klim, Ambrosia and Milkal.

Whole milk powders are very digestible, the proteins of the milk having undergone some change during desiccation.

Once the tin or bottle has been opened, milk powders do not keep indefinitely and in some damp climates become musty from bacterial growth in a few days.

(5) *Skimmed Milk Powders.* For some purposes, such as use in tea and coffee, milk can be better reconstituted from skimmed milk powder and butter than from whole milk powder. Many passenger ships carry for this purpose an apparatus usually referred to as an " iron cow " ; into this is placed skimmed milk powder, butter and water in appropriate proportions, heat is applied through steam coils and the mixture violently agitated ; when the preparation is cooled it fairly closely resembles fresh cow's milk in appearance and taste.

An " iron cow " may be a dangerous apparatus in tropical climates and outbreaks on board ships of food poisoning and dysentery have been traced to it, the apparatus must be thoroughly cleaned and scalded daily.

Skimmed milk powders have approximately the following composition, but there are some on the market which contain as much as 10 per cent. of fat :

Protein	*Fat*	*Carbohydrate*	*Ash*
37	1·5	48	6

There has been some difference of opinion on the use of skimmed milk powder in the diets of infants and children. One view is that, as the powders are deficient in the fat soluble vitamin A and D,

so greatly needed by the young, the use of them should be discouraged, especially where the labouring classes have little education and a low economic status, because the powders, being much cheaper than whole milk powders, are likely to be widely used and lead to much malnutrition. In at least one tropical country this view has led to the prohibition of the importation of skimmed milk powders. The other view is that in many tropical lands the children are brought up on diets deficient in proteins and calcium, and as skimmed milk powder contains these in their best forms its use should be encouraged; one deficiency in the powder, namely, vitamin D, can be amply supplied by the action of the sun, but the great difficulty is the supply of vitamin A.

Skimmed milk powders have been used in institutions such as orphanages with considerable success; but in all cases where they are used a dose of fish-liver oil should be given to the children daily.

(6) *Milk Powders with the Addition of Sugar, Barley, Malt, etc.* There are many proprietary preparations of these and most have deservedly acquired high reputations.

Some of these, intended for infants not being reared on their mother's milk, have part of the caseinogen of the cow's milk removed and lactose added so that the powder will approach the composition of dried human milk. Such preparations are usually designated "humanized."

The following is a brief description of some well-known brands:

Lactogen	Dried whole milk with 10 per cent. lactose added.
Neave's Milk Food	Dried whole milk with lactose and maltose added.
Cow and Gate (Halfcream)	Dried milk less half the fat and lactose added.
Allenbury No. 1	Dried milk less half the protein and lactose added.
Allenbury No. 2	Much the same as No. 1 with malted flour added.
Berina No. 1	Dried whole milk with lactose and wheat flour extract.
Berina No. 2	Much the same as No. 1 with malt extract added.
Milo Food	Dried milk with baked wheat flour and cane sugar added (15 per cent. starch).
Horlick's Malted Milk	50 per cent. dried milk, 26½ per cent. wheat flour, 23 per cent. barley malt, ¾ per cent. bicarbonate of soda.
Carnrick's Soluble Food	37½ per cent. dried milk, 37½ per cent. malted wheat flour and 25 per cent. lactose.
Almata	Casein mixed with eggs, butter, maltose and fruit juice.

Firms which prepare "humanized" milk state on the container that it is humanized, and among them are: Truford, Ambrosia, Dorsella and Sunshine Glaxo, the last has vitamin D and a salt of iron added.

(Many of the firms mentioned in the above list prepare digestible cereal foods which contain no milk, such as Allenbury's Malted Food, Neave's Food, Mellin's Food, Benger's Food, Sister Laura's Food, etc.)

Butter

When cream is churned the fat globules run together to form butter, which consists of 84 per cent. fats, 2 per cent. protein and lactose and 14 per cent. water. Some of the flavour of butter is due to a tang derived from bacterial action during preparation. The water and the protein of butter form a pabulum for bacterial growth, and butter rapidly becomes rancid in warm climates.

Ghee

Because of the poor keeping qualities of butter, ghee is the common tropical preparation of the fats of milk. The milk is boiled and the fats are skimmed off, and again heated to remove most of the proteins and nearly all the water. At a tropical shade temperature of 85° F. the ghee in a bottle separates into two layers—the top layer is transparent oil of low melting-point fats, and the bottom layer is granular and opaque, the opacity being greatest in the lower parts of the bottle, this layer contains more or less solid fats and a little flocculated protein. There is always a slightly rancid taste in good samples of ghee. But much that is sold in the markets of the East as ghee contains various vegetable fats, and the product is often of very high rancidity.

Carefully prepared ghee, which has not been overheated, has good vitamin A values (1,000 units per oz.) and fair vitamin D values.

Both ghee and butter are easily digested.

Cheese

Cheese consists of the proteins and fat of milk. The milk is clotted by rennet or curdled by vinegar or bacterial action. The

whey is removed from the casein and fat, either by draining under a little pressure, in which case a soft cheese is produced such as Gorgonzola, Limburg and Stilton, or the whey is forced out in a press and this produces a hard cheese such as Dutch, American or Cheddar. The mass is deposited in a cellar or other cool place to ripen under bacterial action. The flavour of a cheese is determined by the species of bacteria at work during ripening. Much work is required, however, by bacteriologists before cheese-making becomes thoroughly scientific.

Some cheeses are made from partly skimmed milk, Dutch cheese is an example, but in others the fat is increased by added cream, as is done in the case of Stilton.

The soft cheeses keep in warm climates only in cold storage. They deteriorate so rapidly at room temperature that there is always a considerable wastage ; consequently they may be considered only as a luxury for the wealthier classes.

Even the hard cheeses, which keep well in temperate climates, are apt to undergo decomposition after a few days at room temperature in the tropics.

There is, however, a third class of cheese, which has appeared in recent years in increasing amounts in tropical countries. This is called " processed " cheese ; it is sold in hermetically sealed tins which are packed with convenient portions of the cheese wrapped in tin foil. Many of these cheeses are made in Switzerland. They are prepared by melting the cheese and mixing it with sodium citrate or sodium phosphate and pasteurizing it. This cheese keeps well in warm climates.

Samples of different batches of cheeses labelled with the same name vary considerably in composition and therefore only approximations need be given. Table LXIX records approximate averages from a number of published analyses of five types of cheese.

Cheese is somewhat indigestible because the fats are intimately mixed with the proteins. The richer cheeses, such as Stilton, contain free fatty acids which some people find irritating to the stomach.

TABLE LXIX

	Protein per cent.	*Other nitrogenous matter per cent.*	*Fat per cent.*	*Ash per cent.*	*Calories per oz.*
Dark or pale red hard cheese	20	10	37	5	115
Dutch	21	10	18	6	70
Cheddah	19	9	31	4	100
Stilton	17	7	39	3	118
"Processed" cheese	22	5	27	5	94

EGGS

An average egg of the small hens of the tropics does not weigh more than 1½ oz. compared with the 2 oz. for the eggs of temperate climates. But larger eggs are appearing in the markets following the importation of well-known breeds of poultry from Europe. The weight of an egg is distributed as follows :

Shell	12 per cent.
White	58 ,,
Yolk	30 ,,

The egg is a perfect food for the developing bird as it contains all that is necessary to produce bones, flesh and blood ; but for several reasons it is far from being a complete human food.

The shell consists mainly of carbonate of calcium. The white and yolk differ markedly in composition as shown in Table LXX.

TABLE LXX

	Water	*Protein*	*Fat*	*Ash*
White	86	13	0·25	0·6
Yolk	51	16	31·0	1·0

Hence the yolk of the egg is the most nourishing part. Much of the protein of the yolk is in the form of phosphoprotein ; and the proteins of the whole egg are rich in cystine, tryptophane and other essential amino-acids.

Among the minerals of an egg the white is rich in sodium and potassium salts, and the yolk is rich in phosphorus and iron and fairly rich in calcium. An egg of 2 oz. has about 2 gm. of calcium, but all except 0·13 gm. is in the shell, and as a newly hatched chicken

contains about 0·25 gm., it is obvious that about half of this has been withdrawn from the shell.

Egg yolk contains vitamins A and D and the egg as a whole is rich in vitamin B complex with the exception of nicotinic acid in which it is deficient, it is also deficient in vitamin C. The reason is that the developing chick is able to synthesize these two vitamins, and also inositol. Table LXXI (modified from figures given by E. E. Snell and E. Quales, *J. Nut.*, **22**, 483) shows that the newly hatched chick contains far more inositol and nicotinic acid than was originally present in the egg.

TABLE LXXI

	Pantothenic acid	*Riboflavin*	*Nicotinic acid*	*Inositol*	*Biotin*
Egg . . .	11	2	0·8	70	68
Newly hatched chicken	12	3	19·0	456	68

(All figures γ per gm.)

Probably the chicken cannot synthesize pantothenic acid or riboflavin, and the increases given in Table LXXI are due to analytical difficulties.

Eggs vary in the amount of vitamins they contain, and, when there are insufficiencies in those the chicken cannot synthesize, they will not hatch. Probably the most frequent deficiency in unhatchable eggs is riboflavin ; but vitamins A, D and K may also be deficient.

The eggs of most other birds have much the same composition as hens' eggs ; those of water birds such as ducks, geese and sea birds are richer in fats.

Eggs are valuable and nutritive articles of diet, they contain no carbohydrate and hence are tissue builders rather than suppliers of energy. They should appear frequently in the diets of children, and the fact that the ratio of phosphorus to calcium is higher than is optimum for human growth and the other shortcomings of eggs need not be emphasized as they are easily corrected by milk, fruit juices and other foodstuffs.

Eggs are not indicated in the diets of patients with sprue or pellagra, but during convalescence from these diseases they may not be contraindicated provided the rest of the diet contains little fat and is rich in the essentials deficient in eggs.

CHAPTER XV

DIETS FOR HOSPITALS, PRISONS AND OTHER INSTITUTIONS, LABOURERS' DIETS, INFANT FEEDING

HOSPITAL DIETS

THE diets in many hospitals in tropical countries are inadequate in quality mainly because the authorities do not provide the necessary funds ; and in some cases slow convalescence defeats the aims for good treatment. On the other hand the prescribed quantities of some of the cheaper foodstuffs, such as maize, rice, bread, roots and sugar are often excessive and lead to corruption.

Prescriptions for diets for the non-paying patients of hospitals should comply with the following :

(1) The diets should be adequate in quality and quantity.

(2) The prescriptions should be such as to guard against corruption and waste.

(3) The diets should be reasonably cheap.

A common abuse in hospitals is the admission to the non-paying sections of patients who can well afford to pay. At one hospital, in which this had occurred, such items as green tinned peas, ovaltine, imported apples, Nestle's cream, bacon, jam and other non-essential luxuries had been supplied under extras. The diets should be laid down so that the prescription of extras is cut down to the minimum, this will not interfere with medical prerogatives provided those who determine the diets include the hospital medical officers.

The quantities of the foodstuffs in the diets must obviously be based on caloric values. The ordinary diets in many hospitals contain too much of the staple articles. The convalescent diets and those for surgical patients should have a value of not more than 2,200 calories [1] for all men and women ; and if these diets are properly served so that each patient receives no more than he or she can conveniently consume there will not be more than 10 per cent. of waste from the plates. Some waste is unavoidable and is due to the

[1] In terms of edible part of foodstuffs as served, see Appendix XVI, p. 356.

variable appetites of patients ; such as when a convalescent patient, who has been eating heartily, has a sudden return of fever or an attack of indigestion and leaves much of his meal on his plate. To guard against an insufficiency among large or hearty patients, the staple cereal (maize, rice or bread) should always be allowed as an extra on a medical officer's order.

The diets of the hospitals in different countries must be largely of a pattern with the general diets of the population concerned. The staple cereal may be maize, rice, wheaten flour, or the products of other cereal grains ; roots may or may not be largely consumed ; the only flesh available may be fish in a coastal area, or meat in an inland town ; some races are addicted to potent curries and others avoid them. It follows that a large amount of space would be required to give the diets suitable for use in hospitals in all parts of the tropics. The scheme of diets given below has been modified from one laid down by a committee of medical men, a matron and the sister in charge of a hospital kitchen, and is in use in the non-paying section of the hospitals of Ceylon.

Diet No. 1

Diet not prescribed, or " No " diet.

Comestibles allowed. Eggs, milk, chicken broth, beef broth, mutton broth, vegetable soups, dried milk powder, limes, oranges, pineapples, marmite, arrowroot, sago, cornflour, cereal gruel, sugar, jelly, papaw, bananas and coriander.

Explanation. Diet No. 1 is for acutely ill patients, and as their needs vary greatly the diet must be prescribed from the comestibles allowed.

Diet No. 2

Milk diet A :

Milk 30 oz., barley $\frac{1}{3}$ oz., sugar 2 oz., tea $\frac{1}{6}$ oz.

Extras allowed. Milk, albumen water, eggs, beef broth, liver soup, vegetable soups, cereal gruels, bread, sago, arrowroot, limes, oranges, salt, marmite.

Explanation. Diet No. 2 is the standard milk diet and is more convenient to prescribe than diet No. 1 for patients with high fever or other acute conditions. To prevent waste only 30 oz. milk are prescribed ; more may be given from the extras.

Diet No. 3

Milk diet B :

Milk 40 oz., bread 8 oz., eggs 2, butter ½ oz., bananas 4, limes 2, sugar 2 oz., tea $\frac{1}{6}$ oz., salt.

Extras allowed. Bread.

Explanation. This milk diet is not for patients acutely ill and no extras are allowed. It is satisfactory for many cases "under observation" or undergoing tests for which ordinary full diet is not indicated. It is an expensive diet and must be prescribed with discretion.

Diet No. 4

"*Semi-solid diet*" :

Fish 6 oz., eggs 4, bread 8 oz., milk 30 oz., bananas 4, sugar 2 oz., lime $\frac{1}{4}$, cereal (rice) for gruel 2 oz., tea $\frac{1}{6}$ oz., salt.

Extras allowed. None.

Explanation. This is a diet for early convalescents.

Diet No. 5

"*Half-solid diet*" :

Cereal (rice) 8 oz., bread 5 oz., fish 3 oz. (or beef 3 oz. or eggs 2), pulses (dhal) 1 oz., vegetable leaves 1 oz., vegetables 2 oz., milk 20 oz., bananas 2, sugar 2 oz., tea $\frac{1}{6}$ oz., salt (condiments $\frac{3}{4}$ oz.) (*vide* p. 157).

Extras allowed. Liver, marmite and fruits.

Explanation. Diet No. 5 is half the ordinary full diet No. 6 and half the milk diet No. 3, so that a patient recovering appetite may have a solid meal at midday and milk diet in the evening.

Diet No. 6

Ordinary full diet :

Cereals (rice) 12 oz., bread 4 oz., pulses 2 oz., fish 6 oz. (or beef 6 oz., or dried fish 4 oz., or eggs 4), soup bones 1 oz., vegetable leaves 2 oz., vegetables 4 oz., vegetable oil 1 oz., lime $\frac{1}{4}$, coconut kernel 4 oz. (for preparing coconut milk for curries), sugar 1 oz., tea $\frac{1}{6}$ oz., milk 3 oz., condiments $1\frac{1}{2}$ oz. (*vide* p. 157), salt.

Extras allowed. Rice, liver and marmite.

Explanation. This is the ordinary full diet. Rice is allowed as an extra because 12 oz. may not be sufficient for a large hearty man. (But in practice 12 oz. of rice properly distributed among the patients has been found ample in Ceylon.)

In many countries the cereals (rice, maize, etc.) can be partly replaced by the use of roots (yams, sweet potatoes, etc.) in the pro-

portion of 4 of roots for 1 of dry grain, or 3 of roots for 1 of bread. The coconut in the above prescription adds considerably to the caloric value, and as used in the form of "milk" 1 oz. of coconut has a value of about 100 calories. In many countries coconut and condiments will not be needed in the amounts given above.

Diet No. 7

"T.B." diet:

Cereal (rice) 12 oz., bread 4 oz., fish 6 oz., beef 6 oz., eggs 2, soup bones 2 ozs., milk 30 oz., butter 1½ oz., vegetables 8 oz., bananas 2, lime ¼, vegetable oil ¼ oz., coconut 4 oz., sugar 2 oz., tea ⅙ oz., currystuffs 1½ oz., salt.

Extras allowed. Rice, liver and marmite.

Explanation. This diet is allowed only for patients who have been certified to be suffering from tuberculosis and can consume this diet. To prevent abuse in the use of this very expensive diet, it has been customary to forward a weekly report to the accountants of the number of patients on this diet.

Diet No. 8

Diabetic diet:

Cereal (rice) 6 oz., vegetables 6 oz., coconut 4 oz., vegetable oil ¼ oz., tea ⅙ oz., condiments ½ oz., salt, lime ¼.

Extras allowed. Milk, butter, jam, ghee, pulses, vegetables, eggs, fish, beef, liver, marmite, papaw, bananas, bread and rice.

Explanation. This is a low basal diet, to be gradually increased by the addition of extras.

Diet No. 9

High protein diet:

Cereal (rice) 8 oz., bread 2 oz., pulses 3 oz., eggs 2, fish 12 oz. (or beef 12 oz. or eggs 2), milk 20 oz., vegetables 6 oz., bananas 2, coconut oil ¼ oz., coconut 4 oz., lime ¼, tea ⅙ oz., condiments 1½ oz.

Extras allowed. Sugar, liver, bread, vegetables, rice.

Diet No. 10

New admission diet:

Milk 30 oz., sugar 2 oz., bread 8 oz., tea ⅙ oz.

Extras allowed. Limes and barley.

Explanation. This diet is for patients on admission, pending further examination and prescription of the diet by the medical officers.

Children. The diets for children in hospital should be based upon the amounts of calories, proteins and calcium given on pp. 172 and 175. Milk, eggs and fruit should always be allowed in liberal amounts.

Cereals in Hospital Diets. Wherever possible there should always be two cereals in hospital diets, such as rice and bread, maize and bread, maize and millet, etc.

Vegetables in Hospital Diets. Vegetables are of great importance in the diets of hospital patients and it is necessary to be watchful that they are of good values. Some vegetables such as water gourds, ash gourds and tropical cucumbers have very little values, they are cheap and easily handled; and because hospital contractors are apt to supply them far more frequently than is desirable they should be excluded from the vegetables allowed. In many countries starchy roots such as potatoes and yams will be one of the staple foodstuffs of the prescribed diets, and where this is the case breadfruit, and perhaps jakfruit, may be included with the starchy roots as they have somewhat similar values.

It may be convenient to place the vegetables in a few categories, such as leafy vegetables, gourds, vegetable fruits and roots other than potatoes and yams. And to avoid monotony, vegetables of two categories must be supplied daily, and those of any one category must not be supplied on more than four days a week.

Kitchen Extras, see p. 256.

DIETS FOR LEPER ASYLUMS AND MENTAL HOSPITALS

It has been generally accepted that persons who are compulsorily segregated should be well fed. This is just, but the difficulty is to guard against excessive waste. The author's experience has been that successful pig or poultry farms in the immediate neighbourhood of large asylums are fair indications that the diets of the inmates are excessive in quantity although they may be very poor in quality.

The following is a diet in use in a leper asylum :

> Rice 12 oz., pulses 2 oz., vegetable leaves 2 oz., other vegetables 4 oz., bread 6 oz., bananas 3 (or equivalent in other fruits), sugar $2\frac{1}{2}$ oz., tea $\frac{1}{4}$ oz., milk 3 oz., coconut oil $\frac{1}{4}$ oz., coconut kernel 6 oz., limes $\frac{1}{2}$, green chillies 2, salt $\frac{3}{4}$ oz., currystuffs $1\frac{1}{2}$ oz., fresh fish 8 oz., or beef 8 oz., or dried fish 4 oz., or eggs 4.

There is also a light diet consisting mainly of bread, milk and fruits. The infirmary diets are somewhat similar to the hospital diets given above, but contain a few more luxuries.

PRISON DIETS

Many studies of the signs and symptoms of dietary deficiencies have taken place among the prisoners of jails in tropical countries, and this is an obvious reflection on the diets prescribed for them.

Much has been debated on the matter. It may be urged that prison life should be made as unattractive as possible and that a criminal should receive a poorer diet than he has been accustomed to in free life. The answer to this, for most tropical countries, is that many prisoners come from indigent classes, and when they enter the jails they are already showing signs of dietary deficiencies, or are in a subclinical condition of deficiencies, and that extreme penal diets will seriously affect their health. In one jail the new prisoners were given for a fortnight a penal diet (No. 1) consisting of cereals 21 oz., vegetables 4 oz., coconut 3 oz., lime $\frac{1}{4}$, pepper and salt, and thereafter for the next eleven months they received a more generous penal diet No. 2, and after this were placed on the ordinary diet No. 1, which was nearly but not quite nutritionally sound. The mortality rate in this jail was four times higher than that among the members of the free population of similar age and social status. The elimination of penal diet No. 1 and the improvement of the other diets led to a gradual fall of the mortality rate until it reached that existing among the free population. A jail sentence should not include an enhanced risk of death.

The following diets for labouring class prisoners are in use in the prisons of a tropical country and have proved fairly satisfactory :

Penal diet		*Ordinary No. 1*	*Ordinary No. 2*
Bread	4 oz.	This is the same as penal diet plus $2\frac{1}{2}$ oz. of fish and $\frac{1}{2}$ oz. of sugar daily.	This is the same as penal diet plus 2 oz. of fish, 2 oz. of beef and 1 oz. sugar daily.
Parboiled rice	18 ,,		
Dhal	2 ,,		
Plantains (green)	2 ,,		
Vegetables	4 ,,		
Coconut	6 ,,		
Lime	$\frac{1}{4}$,,		
Onions	$\frac{1}{2}$,,		
Chillies (ripe)	2		
Pepper	$\frac{1}{10}$,,		
Salt	$\frac{3}{4}$,,		

There are punishment diets which are only allowed for three days consecutively.

Prison Hospital Diets should be generous, so that the stay in hospital and the period of convalescence is short. Among the diets in the hospital of a prison is the following "high vitamin" diet :

> Hand-pounded rice 12 oz., dhal 3 oz., liver 8 oz., eggs 2, milk 20 oz., leaves 4 oz., tomatoes 4 oz., marmite ¼ oz., sugar 1 oz., limes 1, salt and various condiments.

There are few tropical countries in which roots do not enter far more largely into the diets of prisons than in the examples given above.

Kitchen Extras are needed in hospitals and other institutions, and these include salt, lard or vegetable ghee, vegetable oil, vinegar, onions, flour, parsley, a few vegetables, soup meat, marmite, extracts of beef (Bovril or Lemco), pepper and a few other condiments.

DIETS FOR LABOURERS

"Much labour in tropical countries is notoriously inefficient at present and there is striking evidence of the extent to which this is due to malnutrition." This statement occurs on p. 92 of the First Report of the British Economic Advisory Council on Nutrition in the Colonial Empire. No one, who has had experience among labourers in mines, on railway construction or on many estates, can have any doubt about the truth of the above statement.

At one time it was a common practice to supply gangs of recruited labourers with an ample quantity of maize, rice or other cereal and to make little or no provision for other foodstuffs ; and the result in most cases was appalling morbidity and mortality rates. Even at the present day there are laws in more than one country by which estate owners must supply their labourers with an amount of rice of a value of somewhat more than 2,000 calories per day (man unit value), but there are no clauses in reference to any other article of diet. Such is the power of legal enactment that although the amount of cereal may be excessive for good health, yet other foodstuffs to help balance the diet may not be substituted for some of the cereal.

The report mentioned above gives examples to show that the employers benefit from the improved performance and contentment of properly fed labourers. For instance, the Central Mining-Rand Group of South Africa, employing 300,000 labourers a year,

found that it was a business proposition to supply them with adequate and properly cooked meals because it resulted in increased efficiency. Again, following an improvement on " the diets of the Union Min'iere properties in the Katanga, the mortality rate between 1926 and 1932 fell progressively from 53 per thousand to 8 per thousand."

The type of comestibles available for the labouring classes varies greatly in different parts of the world.

The following diet was provided by gold-mining companies in Kenya :

" The morning and midday meals consisted of maize-flour gruel ; the evening meal of maize-flour porridge with the following supplements :

Monday	Meat 1 lb. cooked with vegetable (curly kale, carrots, onions and chillies).
Tuesday	Vegetables cooked in ghee (curly kale and tops of leeks).
Wednesday	Meat 1 lb. with vegetables (tomatoes, green beans and onions).
Thursday	Beans or mixed vegetables cooked in ghee and lemons.
Friday	Meat 1 lb. with vegetables (curly kale, mint, beetroot and leeks).
Saturday	Beans or mixed vegetables cooked in ghee. Bananas if available.
Sunday	Soup of green gram and ghee.

Hot cocoa was also served to the labourers."

More use might have been made of grams and other pulses in the above diets.

Very different are the types of diets in use on rubber estates in the East. A survey carried out on a large rubber estate showed that the foodstuffs and the approximate amounts of them were as follows :

TABLE LXXII

	Oz. per man unit value per day	*Constituents*	
Cereals :			
Parboiled rice	23	Carbohydrates	590 gm.
Pulses :		Total fats	24 ,,
Dhall, etc.	2·2	Animal fats	0·2 gm.
Flesh goods :		Total protein	70 ,,
Dried fish	0·5	Animal protein	4·0 ,,
Vegetables :		Calcium	0·23 ,,
Roots, green leaves, etc.	3·0	Phosphorus	1·03 ,,
Coconut	1·3	Iron	18·6 ,,
Sugar	1·1	Energy	2,890 calories
And various condiments.			

The diet shown in Table LXXII is deficient in animal proteins, fats, calcium, vitamin A and riboflavin. And the following type of diet was recommended as an improvement.

> Parboiled rice 16 oz., millet, maize or other cereal 3 oz., pulses 2 oz., vegetable leaves 2 oz., vegetable fruits 3 oz., roots 3 oz., dried sprats 2 oz., dried fish 2 oz., or fresh meat or fresh fish 4 oz., coconut kernel 3 oz., sugar 1 oz.

THE FEEDING OF INFANTS AND "PRE-SCHOOL" CHILDREN

The weaning of healthy infants between the 7th and 12th month usually offers little difficulty provided a supply of milk is available. But untimely weaning, which must take place when the milk of the mother fails, or she falls sick of some serious disease, or becomes pregnant, is a more difficult matter.

The milk of some animal must obviously replace the mother's milk, and the three most commonly available are cow's, buffalo's and goat's milk. The composition of the milk of various animals has been shown to depend to a great extent on the rate of growth of the progeny (*vide* p. 38). The human infant is relatively very slow in growing and human milk contains far less protein and fat than the milk of any of the ruminants.

It follows that whatever milk is used for the early weaning of a child it should be diluted with water. Table LXXIII shows the percentage composition of the milk of three ruminants; and their dilutions with equal parts of water are compared with human milk.

It will be seen from Table LXXIII that the diluted milks are far from being of the same percentage composition as human milk. They all contain far less carbohydrates; and those from cows and goats contain less fat.

The diluted milks can be corrected in respect of the carbohydrates by adding one level teaspoon ($\frac{1}{6}$ oz.) of white cane sugar (or lactose)

to 4 oz. of milk. This renders the milk satisfactory in the case of most infants. Some infants will thrive better if a teaspoonful of cream is also added to each 4 oz. of milk. Buffalo's milk when

TABLE LXXIII

	Human milk	Cow's milk		Buffalo's milk		Goat's milk	
		Undiluted	Diluted 1 in 1	Undiluted	Diluted 1 in 1	Undiluted	Diluted 1 in 1
Proteins . .	1·5	3·3	1·6	5	2·5	4	2·0
Carbohydrates	6·5	5·0	2·5	5	2·5	5	2·5
Fat . . .	3·3	4·0	2·0	7·5	3·7	4	2·0
Minerals . .	0·15	0·8	0·4	0·8	0·4	0·8	0·4

first given to an infant may require a greater dilution than one to one.

When both sugar and cream have been added to diluted cow's milk, it is said to be " humanized." This is an absurd term because the quality of the proteins and fats of human milk is very different to that of the milks of ruminants. The protein lactalbumen is more digestible than caseinogen, and human milks contain equal parts of these proteins whereas a ruminant's milk has about four parts of caseinogen to one part of lactalbumen ; furthermore human caseinogen is more digestible than ruminant's caseinogen.

The fat of human milk is more finely emulsified than that of the milk of ruminants and hence is more easily digested.

The curd of ruminants' milk, formed in the stomach of an infant, is firm and dense, whereas that of human milk is loose and granular.

When the calcium of milk is precipitated by sodium citrate the curd formed is less dense.

The curd of buffalo's milk is particularly dense, and when this milk is used for infant feeding, sodium citrate to the amount of 1–2 grains (0·06–0·12 gm.) per oz. should always be added.

The average normal infant of the tropics requires daily from about 35–40 calories per lb. (0·45 kg.) body weight.

Table LXXIV gives the amounts of cow's milk and sugar required by infants from birth to the 9th month of life.

TABLE LXXIV

	Weight of infant	*Cow's milk*	*Sugar*	*Calories*
1st month . .	6 – 8½ lb.	12 oz.	0·5 oz.	300
2nd ,, . .	8½–11½ ,,	16 ,,	0·75 ,,	400
3rd ,, . .	11½–13 ,,	20 ,,	1·0 ,,	500
4th–6th month . .	13 –16 ,,	24 ,,	1·25 ,,	600
7th–9th ,, . .	16 –18½ ,,	28 ,,	1·3 ,,	700

It must be remembered that the figures in Table LXXIV are rough averages, and that some small weakly infants will not be able to digest these amounts, whereas large healthy infants will require somewhat larger amounts.

All milk given to infants should be "pasteurized" by heating it to 70° C. to destroy pathogenic germs. But the safest practice under tropical conditions is to heat the milk to boiling-point.

A good brand of dried milk powder can replace fresh milk, and under certain conditions is to be preferred to fresh milk.

A little juice, strained and sweetened, from a citrous fruit, guava, tomato or other good source of vitamin C should be given daily. A fish-liver oil or other preparation rich in fat soluble vitamins should be given two or three times a week.

When children are being artificially fed there is one mixture upon which many of them will thrive, it is ripe banana freed from fibre and mashed up in milk. This may be given as early as the third month, but at first a very small amount of the banana should be given.

Weaning of Children. The mother's milk may be supplemented by other milk from about the 7th month. It has been considered that the eruption of the first incisor teeth is an indication to start weaning. Among many races the mothers suckle their children as long as they have milk, and this may extend to two years or more. This is of benefit to the child in those countries where other milk is not available.

The following are types of diets suitable for children from the 9th to 36th months of life.

A Daily Diet for Infants from 9 to 18 Months

1st meal (morning)	Milk and cereal gruel (rice, maize, groats or white flour) with banana and a little fruit juice.
2nd meal (mid-morning)	Milk.
3rd meal (midday)	Bone broth with boiled cereal.
4th meal (afternoon)	Milk and cereal gruel, with a little fruit juice.
5th meal (evening)	Milk.

A Daily Diet for Children from 18 to 36 Months

Breakfast	Milk with cereal gruel or roti, a banana and fruit juice.
Midday	Cereal (rice, maize, millet, etc.) with minced meat or fish or well-boiled lentils, green vegetables and mashed roots. (Sprats or whitebait should be given once or twice a week where possible.)
Afternoon	Milk and cereal preparations or curds may be given.
Evening.	Cereal with soup made from bones.

The wealthier classes will include eggs, and good proprietary foods (such as Allenbury's or Mellin's) in the diets of their children.

MIDDAY MEALS FOR CHILDREN OF THE FREE SCHOOLS

The provision of a midday meal for the indigent among free school children, or even for all free school children, has been considered in several countries, and in a few provision has been made for this meal.

The composition of the meal must obviously depend mainly upon the local dietary habits and the foodstuffs cheaply available in each country.

The following has been prescribed for the schools of an Asiatic country :

Parboiled or hand-pounded rice 4 oz., dhal or gram $\frac{3}{4}$ oz., dried sprats $\frac{1}{2}$ oz., vegetables 2 oz., coconut kernel 1 oz. and a few condiments.

Wherever possible milk or curds should be provided.

Where dietary or nutritional surveys (*vide* Chapter XVI) reveal the prevalence of any particular dietary deficiency this should be corrected in the meal prescribed.

Many deficiencies can be corrected by porridges or thick soups of dhals or grams and vegetables in which powdered yeast has been incorporated.

CHAPTER XVI

PUBLIC HEALTH ACTIVITIES IN RELATION TO NUTRITION : DIETARY SURVEYS, NUTRITIONAL SURVEYS

The provision of adequate diets for the masses of any country has wide references far beyond legitimate medical activities. It is proposed, therefore, first to discuss the medical aspects, and then to indicate briefly the numerous activities needed in other walks of life.

The medical work falls into two general categories : (*a*) *investigational* to discover the nature of the diets of the population and any prevailing deficiencies in them, and to determine the nutritional state of the masses ; (*b*) *work to correct the dietary defects* revealed by these investigations and to give practical application to nutritional knowledge in general.

The investigations will need to be carried out over a period of at least one year and may be divided into four headings : dietary surveys, nutritional surveys, laboratory work and vital statistics.

DIETARY SURVEYS

These are of a qualitative and quantitative nature, the former can be quickly carried out among thousands of persons, whereas the latter requires far more time and work among a limited number of persons. It is advisable that a qualitative survey should first be made so as to obtain a knowledge of all the foodstuffs, and the relative proportions of them, commonly consumed by the classes of various social status in the country. This can be done by a systematic questioning of a large number of school children in the primary, secondary and college class schools, and can be carried out by school inspectors, or trained sanitary assistants. It is advisable that there should be only one visit of inquiry to each school, or the answers of the children may become sophisticated ; and therefore

other schools in the same district should be visited in subsequent seasons.

A description of one of these surveys carried out among many thousands of school children in the various districts of Ceylon will indicate the information which may be gathered. Appendix IX, on p. 340, gives the instructions which were issued to the school inspectors, and the form which was filled in for each child. All the completed forms were sent to a central office where they were studied and summarized. The daily index, which is the number of times a day each child on an average received a particular foodstuff, is obtained by dividing the number of times the foodstuff is named in the forms by the number of children questioned. Table LXXV gives a general summary of the answers received from the boys attending schools for three classes. The table shows that on an average the children of the primary schools receive three meals a day (index 2·99), whereas those of the college schools receive four meals (index 3·97), and those of the secondary schools a little less than four meals a day (index 3·88). The staple article for all classes is rice, and milled rice is used twice as often throughout the whole country as home-pounded rice. Comestibles of animal origin are taken nearly three times more often by the college boys than by the boys of the primary schools, and the secondary boys are intermediate in this respect. Milk is taken by all classes far less often than is desirable, and the children of the primary schools rarely obtain it in any form. The indices of the vegetables indicate variety, and the better-class boys obtain more kinds of these on a daily average than the poorer classes ; the same applies to fruit. The high indices for curries and sambol show that the majority of the meals of all classes are highly seasoned with condiments and those of the poorer classes are pre-eminent in this respect.

The summary in Table LXXV brings out only a few of a large number of points of information which were obtained by this survey. It was found in some towns that unmilled (hand-pounded) rice was seldom, if ever, used, whereas in some rural areas it was the only form of rice consumed. Again, there were areas where a millet (*Eleusine coracana*) formed the main article of diet of the villagers at certain seasons ; and in one particular locality the seeds

TABLE LXXV

General Summary of a Qualitative Dietary Survey

	Primary schools Daily indices			*Secondary schools* Daily indices			*College* Daily indices		
Cereals :									
Milled rice	1·49	2·77	2·99	1·93	2·93	3·88	1·67	2·60	3·97
Unmilled rice	0·74			0·00			0·23		
Other rice foods	0·54			1·00			0·70		
Bread or other cereals	0·22			0·95			1·37		
Pulses			0·44			0·22			0·69
Foods of animal origin :									
Dried fish	0·48	1·12	1·27	0·85	2·15		0·98	3·23	
Fresh fish	0·64								
Meat	0·11			1·19			1·78		
Milk or curds	0·04			0·11			0·47		
Vegetables			1·53			2·36			3·70
Fruits			0·15			0·41			1·28
Curry or sambol			2·32			2·01			2·10

of the lotus plant (*Nymphœa nouchali*) were harvested at the beginning of the dry season and made into various preparations to eke out the stores of rice. The populations along the coasts used mainly fresh fish, but those of the inland parts obtained only dried fish. The surveys also brought out the types of fish eaten and the seasons when shell fish were obtainable. The use of dried sprats among the lower classes often added a much-needed supply of calcium to the diets. In other summaries the vegetables were placed in four categories : leafy vegetables, fruits (such as ladies' fingers (*Hibiscus esculentus*) and plantains), gourds and roots. It was found that leaves from nearly thirty different species of plants were used with varying frequencies, and that in certain areas the fruit vegetables were confined to one or two varieties only, and that in other localities manioc and various yams were consumed in considerable quantities at certain seasons of the year. The seasonal variations in the diets were far more marked in the dry zones than in the wet. Millets, coarse vegetables and certain pulses were avoided by the wealthier classes. Attempts to correlate mortality rates with dietaries brought out some points of interest. The diets in two districts where the mortality was higher than in any other parts of Ceylon consisted mainly of milled rice and fish with surprisingly small amounts of fresh vegetables and fruits.

Quantitative Surveys have much greater values than qualitative surveys, but they present far more difficulties. They must be done by well-trained assistants. Sanitary inspectors and district nurses may be suitable, provided they receive a well-planned course of instruction and are persons able to gain the confidence and co-operation of the members of each family whose diets are to be surveyed.

An important matter is the length of time a survey of the diets of each family should continue, undoubtedly if it is possible it should continue over a period of twelve months. But in these surveys all foodstuffs as prepared for cooking and all waste from the serving pots and platters must be weighed daily, and this entails several visits to the dwelling place of each family ; the father must reveal any extras taken when away at work ; the children on return from school must be questioned, and other details of the families' dietary habits must be watched ; all this constitutes an invasion of the privacy of the home and when carried out over long periods of time is apt to lead to irritability, fatigue and boredom not only of the subjects but of the surveyors, and this will affect the accuracy of the records.

In many cases periods of ten days for each survey will probably be found to be enough for the families and the assistants, and that longer will weary their interest.

The country should be divided into areas and throughout each area the conditions of life of the labouring classes should be more or less uniform, thus there may be a country area with a long dry season where the peasants are all engaged in working their holdings, another country area may be in a wet hilly zone and the majority of the labourers be working on estates, again there may be urban areas where the labourers work in factories.

The seasons and other conditions, which may affect the diets of the people, must be studied and a number of surveys of ten days each should be planned at monthly or two-monthly intervals so as to comprehend the seasons and other conditions. Subjection of each family to more than one survey of ten days should be avoided, but different families living under similar conditions in the same area should be co-opted for subsequent surveys.

Very accurate records may have occasionally been obtained from surveys among educated families, especially when one of the members has been an enthusiastic student, but records of similar accuracy cannot be expected when dealing with the more or less uneducated labouring classes who may be suspicious of inquiries into their private affairs. The aim of most surveys is to find out if the labouring classes are receiving sufficient food and whether or not there are specific deficiencies such as of a vitamin or mineral ; and it is advisable when planning surveys not to make the details too arduous, and to allow minor inaccuracies, provided the main object of the surveys can be achieved.

Where it is customary for the children to receive a diet different from that of the adults, it is obviously necessary that the nature and quality of the foodstuffs in the diets of each member of a family must be recorded and this is an arduous matter, but in many countries the labouring class children partake of a single diet prepared for the whole family, and in this case the quantities consumed by the whole family may be recorded and each child's diet reckoned as a co-efficient of the quantities in the diet of an adult male (*vide* p. 172).

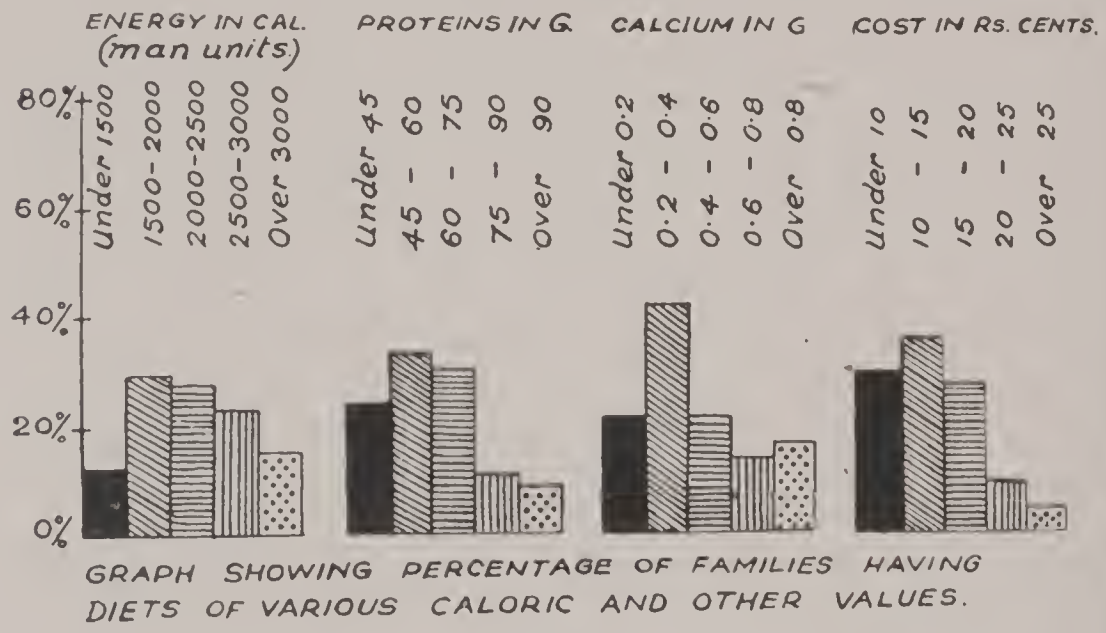
Table LXXVI is a summary in terms of calories, proteins and calcium of surveys carried out among 200 families of Ceylonese peasants at different seasons of the year. There were 463 children in the families, and the quantities of foodstuffs considered to be taken by a child are calculated from the co-efficient for its age group :

TABLE LXXVI

A Summary of Dietary Surveys

	Co-efficient	*Daily calories*	*Daily protein gm.*	*Daily calcium gm.*
Male over 14 years	1·0	2,300	66	0·50
Female over 14 years	0·8	1,840	53	0·40
Child 12–14 years	0·8	1,840	53	0·40
,, 10–11 ,,	0·7	1,610	46	0·35
,, 8–9 ,,	0·6	1,380	40	0·30
,, 6–7 ,,	0·5	1,150	33	0·25
,, 4–5 ,,	0·4	920	27	0·20
,, 2–3 ,,	0·3	690	20	0·15
,, 1–2 ,,	0·2	460	13	0·10

There are reasons why such a summary as appears in Table LXXVI may not be taken entirely on its face value, for instance, it may be suggested that the children obtained the most nutritious articles in the family diets. The summary must be considered with other ascertained facts, for instance, in this case it was found that only twenty-four of the children had received small amounts of milk, and the others had not received any ; and the diets were prepared in a manner that all partaking would receive much the same mixture. Furthermore nutritional surveys were done at the same time as the quantitative dietary surveys and showed that the children were



GRAPH SHOWING PERCENTAGE OF FAMILIES HAVING DIETS OF VARIOUS CALORIC AND OTHER VALUES.

GRAPH 4

stunted and some of them had definite signs of malnutrition. Dietary surveys are not made with analytical balances and no two samples of any foodstuffs have exactly the same composition, therefore the records of such surveys can only be approximate. Taking all facts into consideration in the surveys dealt with above, it may be justifiably concluded that the diets in question were scarcely sufficient in quantity, and did not contain enough protein and calcium for good growth and health of children.

Dietary surveys among the labouring classes usually show that some families are obtaining enough food, others a bare sufficiency and others again not enough during the period of the survey, The following is an example. · Surveys were made for ten-day

periods at different intervals of over fifteen months of the diets of 409 peasant families (comprising 1,874 persons) in various districts of a tropical country ; Graph 4 is a summary of some of the dietary values as taken from the records of these surveys, it clearly indicates the meagre nature of many of the diets, obviously those receiving diets of very low caloric value over a period of ten days must subsequently increase the amount of these or they would not survive. But the labouring classes of the population will not subsist on a shortage of food even for the brief period of ten days if they can obtain a sufficiency.

In some countries feast days are numerous and the generous diets consumed on these days must be taken into account.

NUTRITIONAL SURVEYS

The object of these surveys is to determine the state of nutrition of various groups of persons, such as school children, gangs of labourers, prisoners and sections of the general population.

Malnutrition does not depend entirely on dietary factors and various stresses and infections may play an important part, therefore nutritional surveys must be studied with the results of dietary surveys carried our more or less at the same time, especially in cases where signs of definite dietary deficiencies are not prevalent.

There has been a progressive sequence in this subject from that which has doubtful values to that which is more definite.

At one time considerable attention was paid to the condition of the *subcutaneous tissue*, and this may be of some value in individual cases, such as when it is suspected that the food consumed has been of insufficient caloric value. But with the establishment of knowledge that a state of disease may arise from a single or multiple deficiency of the constituents of food, it has been found that a person may be in a marked state of dietary deficiency without becoming thin or flabby.

In many countries the first assemblage of persons to receive regular medical inspection has been school children, and the details upon which it has been proposed to evaluate the nutritional state are as follows :

(1) *Condition of the Subcutaneous Tissue.* Thickness over the abdomen and fullness within the skin.
(2) *Muscular Tone.* Decided by palpitation by the examiner and strength of grip of the child.
(3) *Facial Expression.* Bright, indifferent or apathetic.
(4) *Alertness.* Various degrees.
(5) *Carriage.* Erect, slack or slovenly.
(6) *Movement.* Active to sluggish.
(7) *Interest and Attention.* Keen to torpid.
(8) *State of the Clothes and General Cleanliness.* This may indicate poverty or neglect.
(9) *The Colour of the Mucous Membranes of the Eyelids and Mouth.* Used as an index of the degree of anæmia.

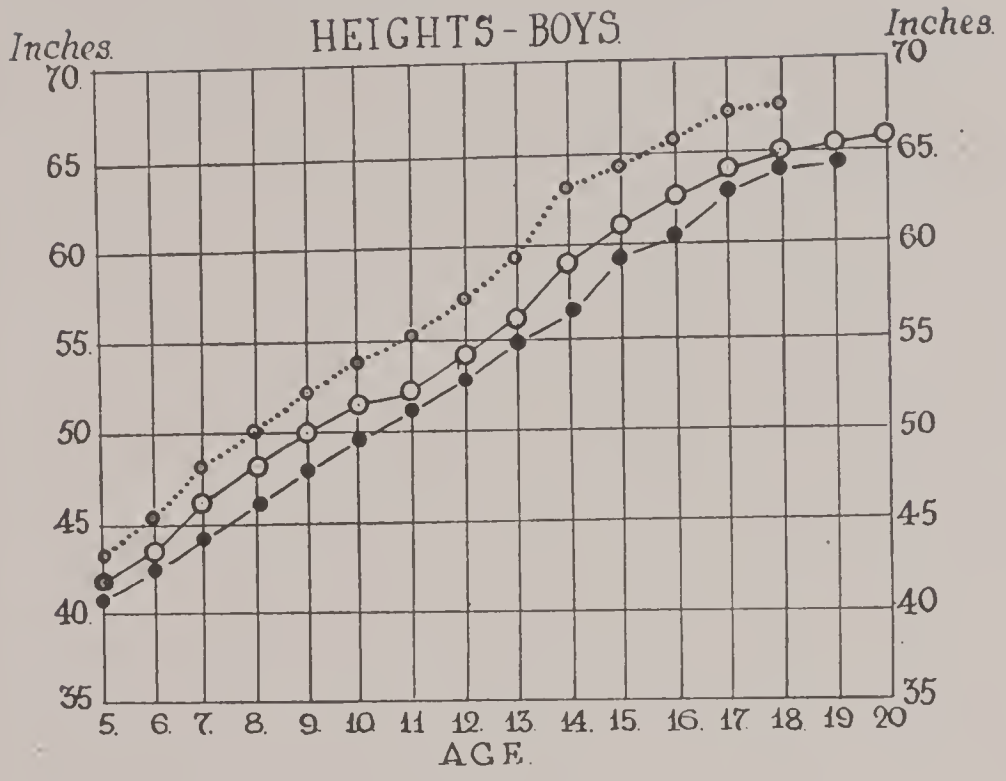
Examination on such points as these depend too much on the subjectivity of the judgment of the examiner, and the results are not definitely conclusive for groups of children and still less for each child taken singly. Derryberry [1] states of such examinations : " Whether a child is rated as malnourished or not depends more on the physician who is the examiner than it does on the condition of the child." This may be true for such examinations standing alone, but they undoubtedly have values when studied in conjunction with the presence or absence of more definite signs of food deficiencies and with dietary surveys.

Growth

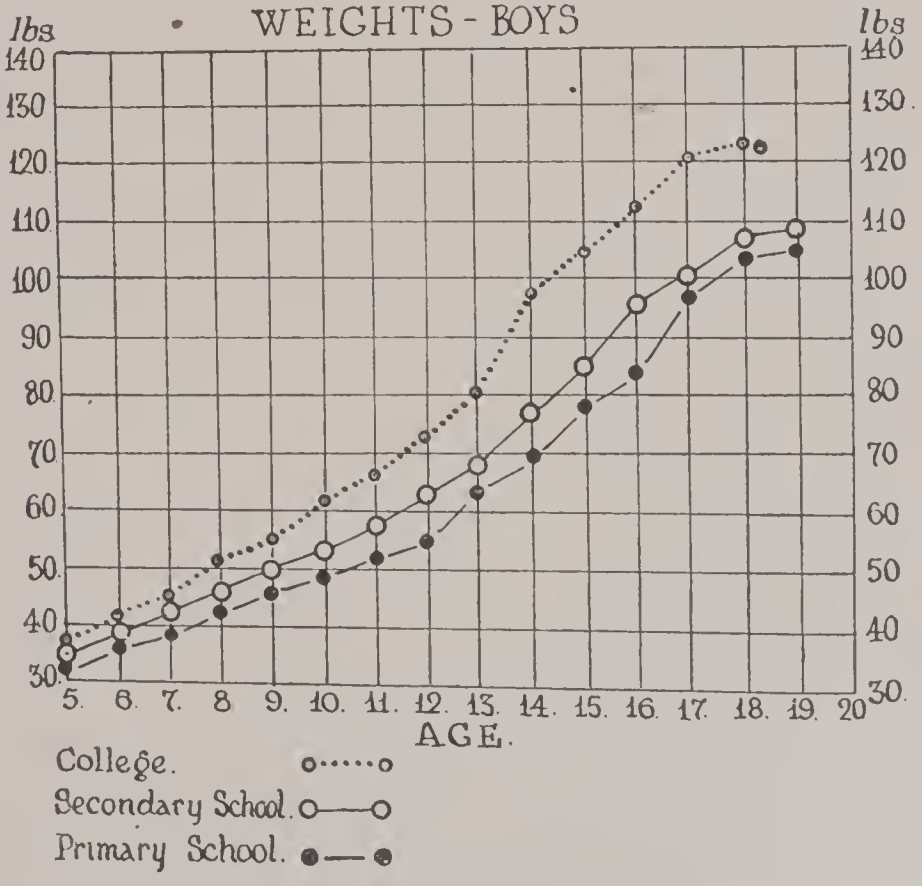
This, determined by weights and measurements of children, has received much attention. At one time it was hoped that the nutritional state of a child might be determined by some correlation between height, weight and age ; and with this in view such tables as those of Baldwin and Wood were drawn up. But the bodily conformation of the human being is so variable that such tables have little value in the case of each child considered separately.

Feeding experiments with young animals have shown conclusively that there is a stunting of growth when their diets are deficient in proteins, certain vitamins or minerals such as calcium

[1] *Pub. Health Rep.*, 53, 263.



GRAPH 5



GRAPH 6

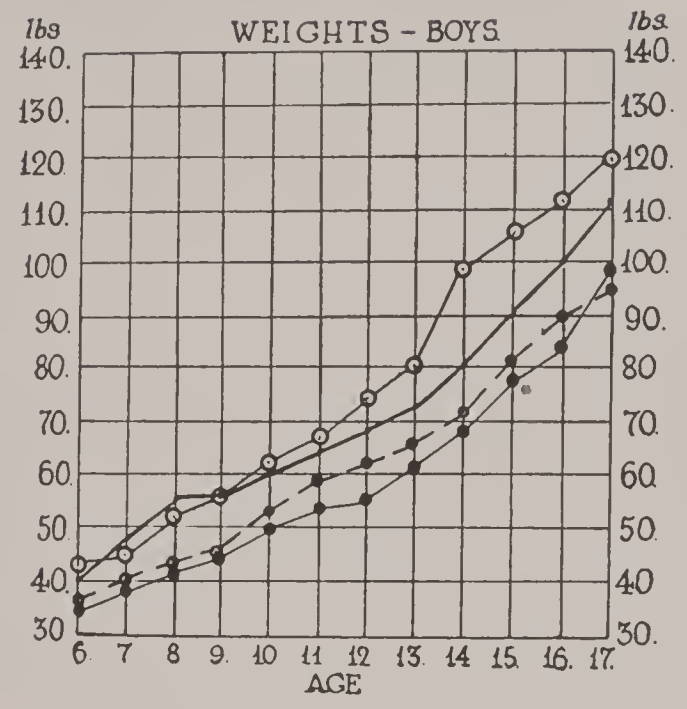
and phosphorus ; and there can be no doubt that deficient diets have a similar effect upon the growth of children.

There are races of small men and of large men, and to what extent their respective sizes have been determined by poor or adequate diets through many generations cannot be decided, but when the size of the average individual of one group of the population is found to be much larger than the size of the average individual of another group of the same race living in the same locality, and the diets of the former are definitely superior to those of the latter, there can be little doubt that a part has been played by dietetic factors. Examples of this appear when the poorer classes are on an average much smaller in height and weight than those of the upper classes of the same race. Graphs 5 and 6 were drawn from the heights and weights of over 7,000 boys among the upper, middle and lower classes in Ceylon,[1] they show marked differences in the size of the individual of the different classes, for instance, the boys of the upper classes were five inches taller and weighed 20 lb. more than the boys of the lower classes at the age of fifteen.

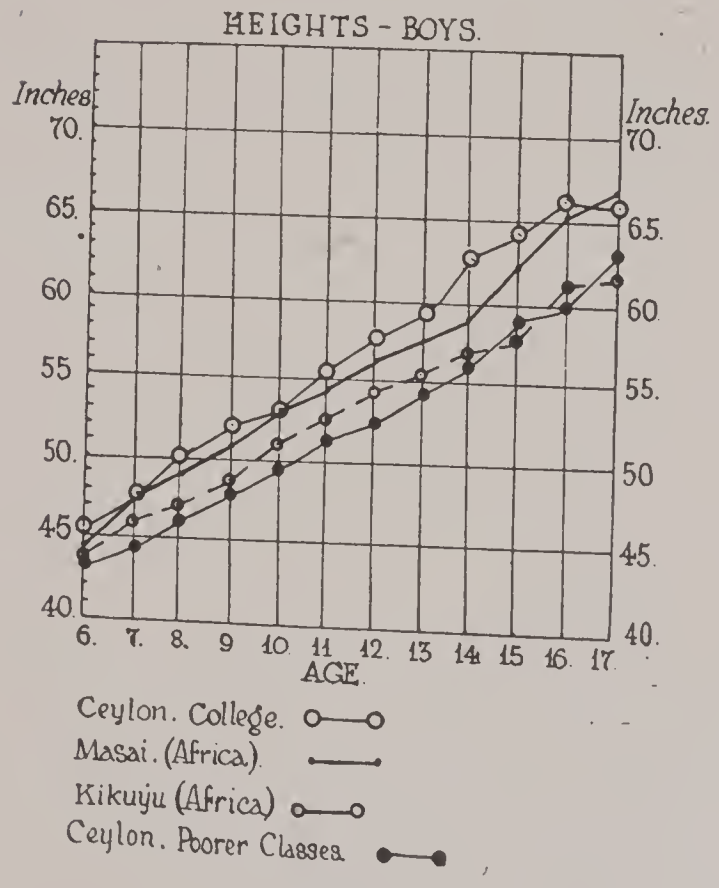
Orr and Gilks [2] studied two East African tribes, the Masai and Akikiyu, who are neighbours ; they are of much the same origin, the former, however, are a pastoral tribe and live mainly on milk and meat, whereas the latter are agricultural and more or less vegetarian. The Masai were found to be far better grown and stronger than the Akikiyu. Graphs 7 and 8 compare the sizes of the males of these tribes with those of the males of the upper and lower classes in Ceylon.

The rate of growth of children is not uniform from year to year ; there is a rapid increase in growth for all classes of boys between the ages of five and eight, but it is more marked in the boys of higher social status ; then for the next three years there is a slackening in the rate of growth, and this is also more marked in the upper class boys ; after this there is an acceleration during the years eleven to fourteen. Thereafter the rate is not similar for the upper and lower classes, and between the ages of fourteen to seventeen college

[1] Nicholls, L. (1936), *Cey. J. Sci.*, Sect. D, IV, 1.
[2] *Med. Res. Coun. Rep.* (1931), No. 155.



GRAPH 7

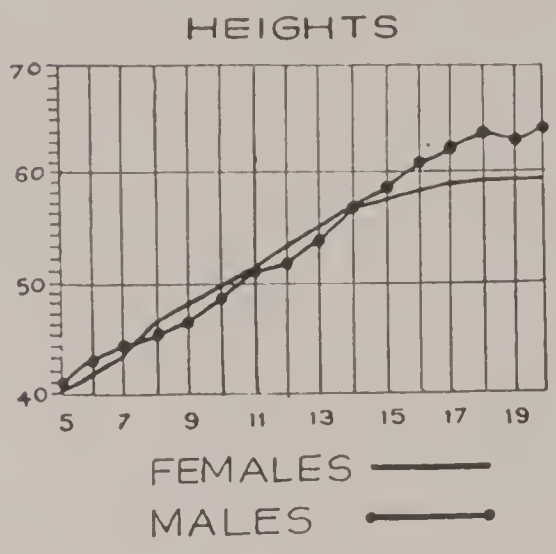


GRAPH 8

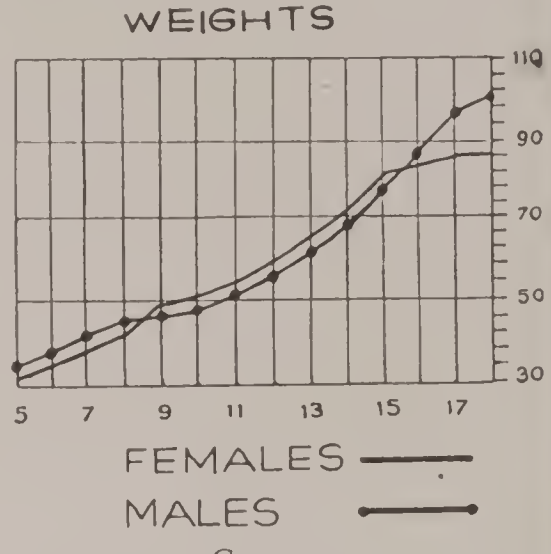
boys grow much less rapidly than the boys of the labouring classes ; it appears that when the rate of growth during childhood has been retarded by any cause, such as a poor diet, some compensation in the form of accelerated growth occurs during adolescence.

The growth of males and females is not the same, females mature earlier. Graphs 9 and 10 compare the heights and weights of males and females of the labouring classes of Ceylon during their years of growth.

In each school there should be a measuring standard and a balance,



GRAPH 9
Heights of males and females compared



GRAPH 10
Weights of males and females compared

so that the heights and weights of the students may be taken periodically and a watch kept for lessening or abeyance of growth. But tables of the natural pulsations of the children of each particular race and country is a primary necessity for a rational consideration of the growth curves of each child.

Indications of the State of Nutrition from Certain Bodily Conformations

Stunted growth may be accompanied by some alteration in the build of the body, and indices based on various bodily measurements have been used because they are considered to be indications of the past or present nutritional state. Perhaps the most used of these is the A.C.H. index (*vide* Appendix XI, p. 343). This index has been found to be of no definite value when applied to Indian and Ceylon children.

PLATE IX

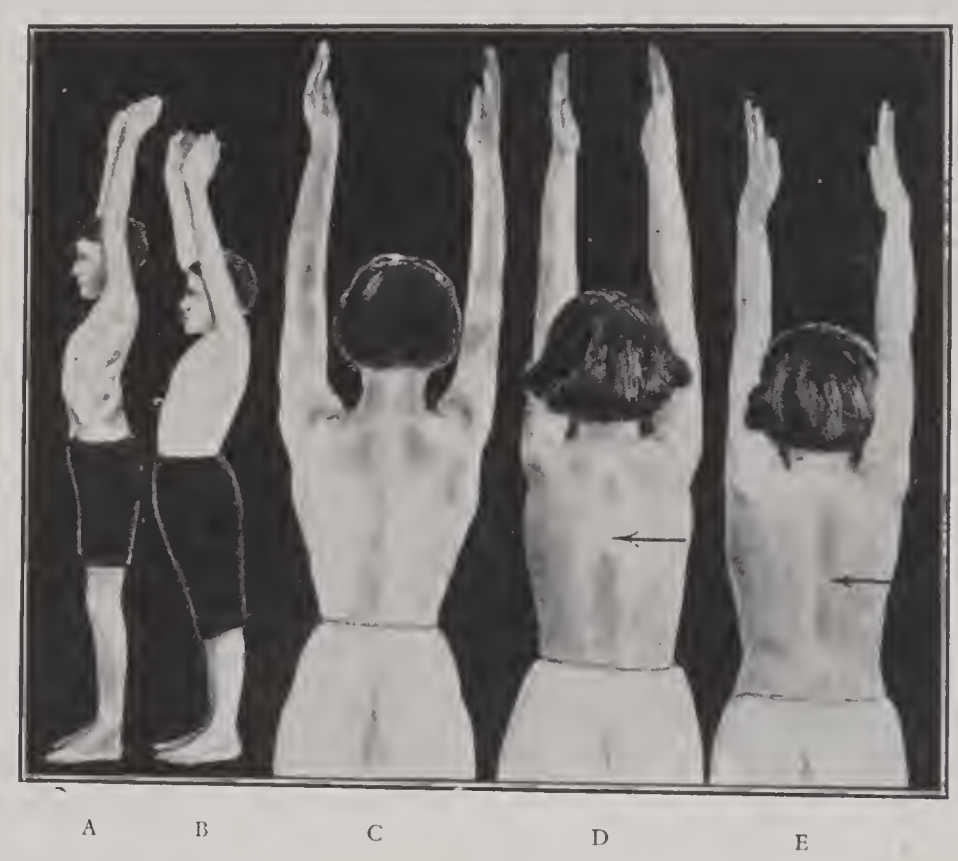


FIG. 19.

THE SIGN OF THE MEDIAN-DORSAL FURROW

[*To face page* 275

The Sign of the Dorsal Median Furrow (*or Knudsen-Schiötz Sign*), supposed to depend on the normal development of the spine and thorax under the influence of a properly balanced diet, has received considerable attention. It was proposed first by Knudsen of Denmark, and a great protagonist of it has been Professor Schiötz. When an alert, well-developed child raises his hands straight above his head he holds the curves of his limbs and body more or less in a straight line (A, Pl. IX, Fig. 19), and the furrow over the spine is continuous, well defined and narrow (C, Pl. IX, Fig. 19). On the other hand a less well developed child cannot readily dispose the curves of his limbs and body around a more or less straight line when he raises his hands above his head (B, Pl. IX, Fig. 19) and the dorsal median furrow is irregular and broken (D and E, Pl. IX, Fig. 19 ; the arrows point to breaks in the furrow).

The value of the sign has yet to be established under tropical conditions.

Definite Signs of Malnutrition

Many definite signs due to deficiencies of various food constituents have been studied in recent years ; they should always be looked for in nutritional surveys, and where they are fairly prevalent surveys may be based on them alone.

Hair. There is a tendency in some types of malnutrition for the hair to lose its glossiness and become dry and staring with scurfiness of the scalp.

Skin and Subcutaneous Tissue. Six definite conditions should be looked for : (1) Dry skin ; (2) Phrynoderma ; (3) Pellagra-like eruptions ; (4) Scrotal dermatitis ; (5) Hæmorrhages ; (6) Œdema.

(1) *Dry Skin.* The normal gloss of the skin is lost from deficient secretion from the sweat and sebaceous glands, and the skin becomes dry with a fine scaliness, usually the epidermis in the front of the shins will be broadly fissured into a mosaic pattern. The plaques of this eruption may be shiny in contrast to the matt appearance of the skin of the rest of the body. This has been called *Mosaic Eruption.* Dry skin is common among school children who receive insufficient vitamin A.

(2) *Phrynoderma,* due to changes in the sweat and sebaceous

glands, has been described under vitamin A deficiency (p. 82) (*vide* Plate II, p. 82). This eruption has been found prevalent among prisoners and other groups of adults in several parts of the world. Its frequency among the children of the poorer classes has been recorded by observers in Africa, India, Burma and Ceylon, and ranges from 27·6 per cent. for a group of nearly 1,000 children examined by Loewenthal in East Africa to about 14 per cent. given by Aykroyd and Rajagopal for certain groups examined in India. An examination of many school children can be done rapidly by inspecting the extensor surfaces of the arms extending up to about 6 inches above the elbow. The skin should not only be viewed but also should be felt, and a " nutmeg grater " feel produced by the enlarged sebaceous glands is characteristic.

(3) *Pellagra-like Eruptions* have been described from countries where the classical type of pellagra does not occur or is very uncommon. The commonest form occurs as dark irregular patches having a texture which recalls thin parchment, these appear on the cheeks, back of the hands and other exposed surfaces; if there is peeling of the epidermis small areas of a lighter colour appear and give the eruption a blotchy appearance. The more advanced changes such as bleb formation or marked ulceration are not seen among school children.

(4) *Scrotal Dermatitis*, due to atrophy and peeling of the superficial layers of the epidermis leaving shallow raw eczematous areas. This is often accompanied by a sodden œdematous condition of the deeper layers of the skin and subcutaneous tissue, and the scrotum is larger than normal. This eruption has been found fairly prevalent in prisons or among gangs of labourers on a monotonous improper diet. Prejudice in some countries against exposure of the sexual organs prevents the examination of school boys for this eruption. Scrotal dermatitis is an ariboflavinosis.

(5) *Hæmorrhages.* In semi-desert lands or during long dry seasons fresh fruits and vegetables may be unprocurable and the resulting deficiency of vitamin C may give rise to small hæmorrhages into the skin. Surveys for the prevalence of this deficiency may be carried out by using some suction or pressure apparatus (*vide* p. 334).

(6) *Œdema* of the skin and subcutaneous tissue, commonly called nutritional œdema, usually starts around the ankles and later may be present throughout the body. It sometimes occurs among malnourished children, and slight pitting on pressure of the lower parts of the legs may be found among a small percentage of the children attending the schools for the poorest classes. Gangs of labourers being medically inspected should always be examined for mild degrees of nutritional œdema.

The cause of this œdema is usually a shortage of protein in the diet, but a deficiency of vitamin B_1 and other factors play a part.

Mouth. The conditions to be looked for are : angular stomatitis (cheilosis), eroded tongue, spongy gums, and decay, irregularities or fluorosis of the teeth.

Angular Stomatitis (*vide* Plate IV, Fig. 7, p. 103) is a superficial erosion of the mucous membrane of the lips at the angles of the mouth, when the lips are more extensively affected the term cheilosis is used. It is due to riboflavin deficiency.

Eroded Tongue occurs as irregular patches of superficial erosion of the mucous membrane of the tongue. These patches are red and are in marked contrast to the unaffected areas of the tongue which show the grey-white duvet of the normal fur. "Geographical tongue" is a term which has been used for this condition and is expressive of the irregular patterns often produced by the erosion. Eroded tongue is due to riboflavin deficiency and has often been taken together with angular stomatitis in nutritional surveys under the term "sore mouth." This type of sore mouth is, after phrynoderma, the most frequent sign of a dietary defect among the indigent classes of many tropical countries. It has been found prevalent in prisons, orphanages and among the labouring-class school children. It may be particularly common among pregnant and lactating women.

A more acute stomatitis is sometimes an early sign of pellagra, the onset of this in most cases is probably determined by the double deficiency of nicotinic acid and riboflavin. It is probable that other deficiencies may lead to sore mouth, such as a deficiency of pyridoxine.

Spongy Gums. This is the commonest sign of vitamin C

deficiency. There is tendency to bleeding which may be easily started when the gums are pressed. A secondary stomatitis often occurs from bacterial invasion and leads to enlargement of the lymphatic glands in the upper part of the neck.

Teeth. The causes of dental decay are not definitely known; possibly they may be placed in two general categories—dietary defects and lack of cleanliness.

Dietary Defects. M. Mellanby has stressed the importance of vitamin D for the healthy formation of teeth, and suggests that a deficiency of it is the main factor in most cases of dental decay among children in Great Britain; this may be so, but it is certainly not the cause of dental decay among children in many tropical lands, where caries is prevalent among children who do not show the slightest sign of rickets. Labouring-class children having diets deficient in calcium, vitamin A and/or vitamin C show a far higher incidence of caries than the wealthier class children in whose diets these shortages do not occur.

Lack of Cleanliness. Possibly this is the commonest cause in many parts of the world where a daily cleansing of the teeth is not a habit, and the teeth become clogged with tartar and minute accumulations of decaying foodstuffs.

There is evidence that the teeth of savage tribes are freer from decay than the teeth of civilized races. The urgencies of life among savages are such that the infants and children survive only when there is an ample diet for them, and much of the food being coarse and tough exercises and cleans the teeth; further, most savages spend much time cleaning their teeth with bone or wooden picks.

Many of the races among the teeming populations of Asia are in a state of semi-civilization, and dental decay is very prevalent. It is not uncommon to find children in whom the deciduous teeth have been reduced to rows of blackened decayed stumps.

When children are being examined for dental decay it is always advisable to examine a number from different classes, so that the relative prevalence may be studied with the diets they receive. For instance, in one survey the incisor teeth of the children between the ages of five and eight were examined in the free schools and one preparatory college school, the result was that among 278 poor

class children there were 239 decayed upper incisors, or a percentage of 21·4 of all their upper incisors, but among 134 better class children there were only 22 decayed upper incisors, the percentage being 3·9. The lower incisors are far less liable to decay, and eight were found decayed among the former and only one among the latter. (The reason why only incisor teeth are examined in some surveys is because it requires much time with probe and mirror to examine all the teeth in a child's jaws.)

The diets of the free school children were deficient in protein, calcium, vitamin A and riboflavin, whereas these deficiencies did not exist in the diets of better class children.

The teeth should also be examined for the type of mottling due to fluorosis (*vide* p. 306).

Advanced degrees of malocclusion and irregularities of the teeth are far more common among the poorer classes in the tropics than among the wealthier classes, and this may be due to malnutrition in infancy causing a stunting of the fore parts of the jaws (*vide* p. 29).

Œsophagitis. Sore mouth due to riboflavin deficiency may extend to the pharynx and œsophagus, and the patient's chief complaint is a scalding sensation on swallowing. This condition has been found in prisons, but it is most common among the women who are in the later stages of pregnancy or are lactating.

Eyes. These should be examined for xerophthalmia, increased pigmentation of the bulbar conjunctiva, Bitot's spots (*vide* p. 80), ariboflavinosis (*vide* p. 104) and the subjective sensation of night blindness (*vide* p. 79).

Bones. When the surveys are among children, they should be examined for epiphyseal enlargements and other deformities of rickets.

Neuritis. The predominant cause of nutritional neuritis is a deficiency of vitamin B_1, but changes are found in the nerves and spinal cords of animals which have been fed on diets lacking other vitamins. It is probable that cases of mild neuritis are caused in human beings by a combination of deficiencies, in other cases there is the added factor of some toxic substance in the food, as in lathyrism (q.v.).

The early signs of neuritis are pain, numbness and tingling sensa-

tions in the hands and feet, and vague rheumatic pains in other parts of the body. (But the records of subjective sensations usually have small values in nutritional surveys.) The muscles become more sensitive to pressure, and a useful procedure when examining groups of children, prisoners or others is to squeeze the muscles of the calf of each in turn, and a degree of compression which is ignored by persons in a normal state of health is ill-borne in the early stages of neuritis.

Retro-bulbar neuritis has been recorded in children in Nigeria and attributed to malnourishment. Possibly there are two factors, a deficiency and a food poison. The condition is characterized by increasing dimness of vision.

Anæmia. This can be determined more or less accurately only with the microscope and other instruments of precision, but a general impression may be gained by an inspection of the membranes of the mouth and eyelids. The anæmias of malnutrition, hookworm infestation and malaria are so closely interrelated in most tropical countries that one of them can never be studied apart from the other two (*vide* p. 42).

Infections. Dietary deficiencies leading to a lowered resistance to bacterial invasion may require consideration in some surveys, such as in outbreaks of dysentery or pneumonia in prisons or other institutions.

Mentality. There can be no doubt that malnourishment leads to apathy, laziness, irritability and general unrest; but here again these may follow any cause of ill-health. In some nutritional surveys it is appropriate with proper reservations to consider the mental state of the subjects. Alert, active, happy or even mischievous school children are probably well nourished, whereas those who are apathetic and not playful should be selected for further inquiry into their state of nutrition. Laziness, discontent, strikes or mutiny among gangs of labourers or prisoners have reasonably been attributed to ill-health from malnourishment, and where the diets can be shown to be defective the medical authorities have a right to suggest the remedy.

Table LXXVII gives a summary of the signs of dietary deficiencies which may be useful in nutritional surveys.

TABLE LXXVII

	Signs	*Attributable to deficiencies of:*
Growth	Stunted growth.	Various factors — proteins, minerals or vitamins.
Hair	Dry and staring.	Vitamin A (general malnutrition).
Skin	Dry skin.	Vitamin A.
	Phrynoderma.	,,
	Dermatitis of exposed surfaces.	Nicotinic acid.
	Scrotal dermatitis.	Riboflavin.
	Hæmorrhages.	Vitamin C.
	Œdema.	Protein.
Mouth	Angular stomatitis.	Riboflavin.
	Eroded tongue.	,,
	Spongy gums.	Vitamin C.
	Decayed teeth.	Various factors.
Œsophagus	Soreness on swallowing	Riboflavin.
Eyes	Pigmentation.	Vitamin A.
	Night blindness.	,,
	Bitot's spots.	,,
	Xerophthalmia.	,,
	Vascularization near limbus.	Riboflavin.
Nerves	Neuritis.	Vitamin B_1 and others.
Blood	Anæmia.	Various factors.
Bones	Signs of rickets.	Vitamin D (sunlight).
Infections	Predisposition to dysentery and respiratory infections.	Vitamin A and others.

Biochemical Methods for the Evaluation of the State of Nutrition

There are chemical methods by which the amount of certain minerals and vitamins may be determined in the blood and urine. Many of the methods are too complicated for nutritional surveys, but the rapid advances of biochemistry give promise of a time when simpler methods will be widely used.

Vitamin A in the blood has been determined by the antimony trichloride test and spectrophotometrically, neither method has been of marked value. One difficulty has been the rapid changes in the amounts of the vitamin in each person's blood. The amounts of thiamine in blood and urine have been determined by the thiochrome method and the rat bradycardia method, both are too complex for nutritional surveys.

Riboflavin is excreted as uroflavin which has been measured by a fluorometric method.

Nicotinic acid is excreted as trigonellin and this can be measured (p. 111).

The quantity of vitamin C in the urine is easily determined by the dichlorphenolindophenol method and has been used in surveys (p. 335).

Also the changes in the quantities of certain substances in the blood in states of deficiency may be measured ; the two examples of this are the lessened calcium and phosphorus in the case of vitamin D deficiency, and the increase in pyruvates in the case of thiamine deficiency.

LABORATORY WORK

This falls into two categories—the analyses of foodstuffs and physiological investigations.

(*a*) *Analysis of Foodstuffs.*[1] The vitamin and mineral content of foodstuffs grown locally or imported may need to be determined. Where large quantities of milled cereals are imported there should be checks on the vitamin content at frequent intervals.

Investigations for such poisons as prussic acid, selenium and possibly sapotoxins in foodstuffs and fluorine in water are needed in many countries.

The detection of adulteration of milk, butter and other foods may be among the activities of the laboratories of the health authorities.

(*b*) *Physiological Investigations.*[1] Some of these directed to the evaluation of the nutritional state have already been indicated (p. 281).

Other investigations, especially in the form of balance experiments, are needed among different races living under various dietetic and climatic conditions, because they may reveal biological adaptations and other factors which will indicate that dietary requirements are not exactly the same for all human races.

[1] The nature and the amount of work which falls under these headings is such that in most tropical countries it cannot be carried out satisfactorily except by a separate division of the Medical Department.

CHAPTER XVII

PUBLIC HEALTH ACTIVITIES (*continued*) : VITAL STATISTICS ; PRACTICAL APPLICATION OF NUTRITIONAL KNOWLEDGE

VITAL STATISTICS

The general state of health of the population of any country is reflected in the vital statistics ; and the death rates, the causes of death, the prevalence of infantile mortality and stillbirths are criterions of health and prosperity or the lack of them. The death and birth rates as recorded by the Registrars-General of most countries are fairly accurate ; but it is otherwise with the returns of the causes of death, and even in advanced countries these are far from satisfactory, and this is mainly due to faulty diagnoses and the usage of indefinite terms such as asthma, purpura, dropsy, heart failure, pyrexia, etc. In some tropical countries, such as parts of India, where medical men are few and far between, the diagnoses of the cause of death are made by poorly educated registrars who obtain the information by questioning the relatives and others who had been in contact with the deceased during the last illness. It might be considered that records of the causes of death drawn up from these sources would be of little or no value ; but this is not the case, and much valuable information may be obtained by a study of the reports of Registrars-General.

Infantile Mortality

Table LXXVIII gives the death and birth rates and the infant mortality for a number of countries, and shows how widely these vary in different countries ; and generally the figures are favourable where there is a good economic standard among the labouring classes. The infantile mortality rate depends on many factors, such as ignorance or insanitary habits of the parents ; but it is to a great extent a reflection of economic standards and needs study from the nutritional aspect.

TABLE LXXVIII

	Deaths per 1,000	Births per 1,000	Infant mortality per 1,000 births		Deaths per 1,000	Births per 1,000	Infant mortality per 1,000 births
New Zealand	8·3	18·0	33	Austria	15·0	16·9	117
Australia . .	8·9	18·4	44	Italy .	15·0	25·3	117
Netherlands .	9·4	22·2	50	Estonia	15·7	17·2	108
South Africa	9·7	25·7	67	France	16·6	17·9	84
Canada . .	10·8	24·2	86	Hungary	16·9	24·6	171
Denmark .	11·1	18·6	82	Greece	17·1	30·0	96
Germany .	11·6	17·6	94	Bulgaria	17·4	30·8	147
United States	11·8	19·4	68	Spain .	17·8	28·5	124
Switzerland .	12·1	17·2	53	Japan .	19·4	33·1	135
England . .	12·2	16·1	66	Chile .	23·8	38·4	229
Argentina .	12·3	27·7	—	Ceylon	24·0	38·7	172
Belgium . .	13·7	18·4	95	Egypt .	26·0	44·1	152
Irish Free State . .	14·4	19·6	69				

Table LXVIII is from the New Zealand Official Year Book 1935.

TABLE LXXIX

Causes of Infant Mortality in Ceylon

Yearly average (1924 to 1933)

Causes	*3 months and under*	*3 months and under 1 year*	*Total under 1 year*	*Percentage of infant deaths from all causes*
Convulsions	6,617	2,804	9,421	27·5
Tetanus	47	5	52	0·15
Diarrhœa	112	335	447	1·3
Bronchitis	127	152	279	0·8
Pneumonia	194	594	788	2·3
Enteritis	115	181	296	0·86
Debility			7,257	21·2
Diseases of the integumentary system	★	★	9,050	26·4
Prematurity	★	★	2,164	6·3
Mandama (rickets) . . .	★	★	774†	2·2
Other causes	★	★	3,559	10·3

★ Not available. † Estimated from one year's return.

A consideration of some of the details of infantile mortality in Ceylon may be taken as an example of such a study. Until very recent years the number of infants dying within one year of birth was about 170 per 1,000 births. The causes of these infantile deaths as given in the Annual Reports of the Registrar-General are shown as a yearly average for the decade 1924 to 1933 in Table LXXIX.

Thus 75 per cent. of all infant deaths have been returned as due to convulsions, debility or diseases of the integumentary system, and another 8·5 per cent. as due to prematurity or mandama.

Convulsions. A convulsion is symptomatic and may be due to one of many causes. The rigors of malaria and other acute infections in adults are replaced in children by convulsions, and it is probable that many of these deaths have occurred from acute infections, particularly in malarious areas. But an analysis of 257 deaths from convulsions in a non-malarious area showed that 51 occurred during the first week of life, and 84 within the first month of life. Many of these infants appear to be of low vitality and all else that is apparent is that they pass into convulsions and die. This cause of infantile death is relatively uncommon among the wealthier classes, and this and other evidence which will be mentioned later suggests that they are due to malnutrition of the mothers. Possibly some of them may be tetany from calcium deficiency.

Debility. Under this heading are included all returns of marasmus and malnutrition.[1] The majority of these deaths take place in the first two weeks of life; the infants are puny and born of ill-nourished mothers.

Diseases of the Integumentary System. The term "rathé" sanctioned by vedaralas (native doctors) and registrars, is used for almost all skin diseases of infancy, and deaths attributed to rathé are placed by the Registrar-General under the heading "diseases of the integumentary system." The examination of a large number of infants in whom this disease had been diagnosed has revealed varieties of pyodermias of which the commonest are impetigos and ecthymas. The eruption in most cases is widely spread over the body; and the primary infecting organism is usually a streptococcus.

[1] The term "malnutrition" dos not occur in the reports of Registrars-General; possibly it would be considered a reflection on the body politic.

As the generalized eruption subsides many children become secondarily infected with *Staphylococcus aureus* and develop chronic furunculosis from which the majority do not recover. Other deaths in this category might fall under the indefinite term "infantile pellagra."

Mandama (*vide* p. 153). The Registrars-General reports show that the average number of deaths for the decade 1923 to 1932 under the heading *rickets* was 4,339, which is a little more than 3 per cent. of all the deaths in Ceylon, only about 17 per cent. of these deaths occur in the first year of life. Rickets occurs in Ceylon, but is uncommon, and in marked cases there is usually a history that the child had had some prolonged illness and had been confined in a dark room away from sunlight. When records of the causes of death were first kept, the International System was adopted which had been drawn up mainly for temperate climate conditions and European medical officers were asked to explain the terms in local use and sanctioned by vedaralas. For reasons which are not now apparent it was decided to record deaths from mandama under the heading rickets.

The relative frequency during the first year of life and in later childhood of deaths from rathé, convulsions and mandama are as follows :

	Per cent. under 1 year	*Per cent. over 1 year*
Rathé . . .	93	7
Convulsions . .	54	46
Mandama . .	17	83

Stillbirths. Wherever infantile mortality is high the incidence of stillbirths is also high. Since the notification of stillbirths was made compulsory in Ceylon there have been recorded yearly about 80 stillbirths per 1,000 live births, but many abortions in the later months of pregnancy are not included among these.

A study of the weights at birth of children of parents of different social status throws some light on the cause of stillbirths and infantile mortality.

There is in Ceylon a lying-in home where there are two sections —one for the poorer classes and one for paying patients. Table

LXXX gives the weights of 2,038 infants of the labouring classes for consecutive births, and 216 infants of the paying patients for consecutive births during the same period.

TABLE LXXX

	Non-paying section				Paying section			
	Males		Females		Males		Females	
	No. born	Per cent. of births	No. born	Per cent. of births	No. born	Per cent. of births	No. born	Per cent. of births
4 lb. and under .	72	5·5	70	7·1	0	0	1	0·9
4–5 lb. . .	173	15·9	178	18·6	6	5·4	12	11·3
5–6 lb. . .	383	35·5	333	34·9	20	18·1	17	16·0
6–7 lb. . .	306	28·2	277	29·0	35	31·6	42	39·6
over 7 lb. .	150	13·8	95	9·9	49	44·5	34	22·0
Totals .	1,085	100·0	953	99·5	110	99·6	106	99·8

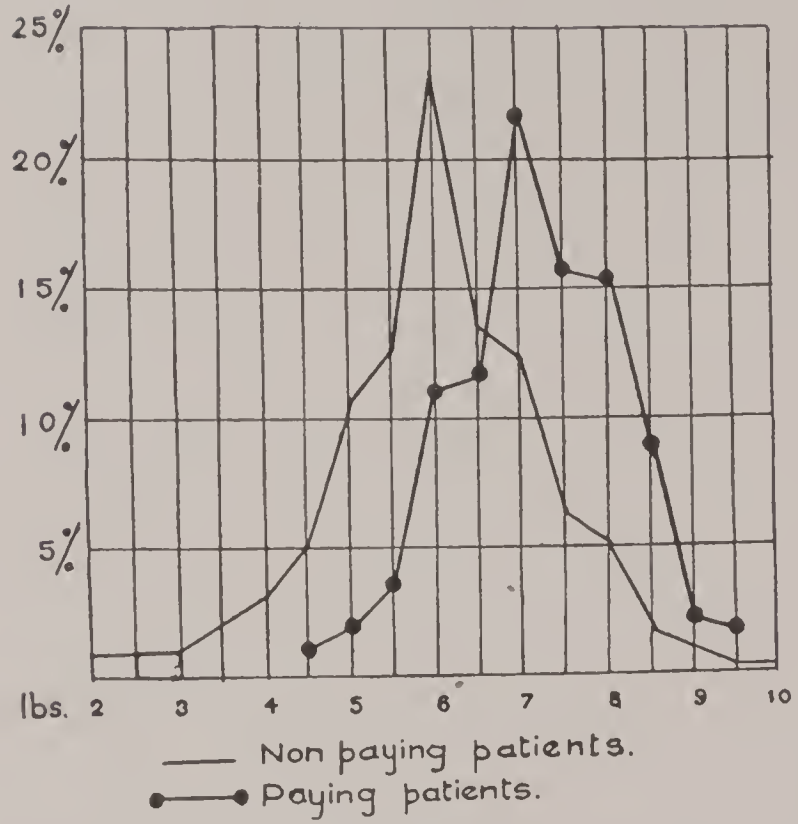
The average weight of the infants was 6·06 lb. for males and 5·94 lb. for females of the labouring classes, and 7·05 lb. for the males and 6·77 lb. for the females of the paying classes. Graph 11 shows the percentage of frequency of weights[1] of the newborn of males of the two classes.

The Ceylonese are a race of small people, and it might be suggested that the weights of their infants at birth would be relatively small, but when graphs are drawn from the weights of British newborn given by Bruce and Murray [2] they register almost exactly with the graphs of the weights of the infants born in the paying section of the Ceylon lying-in home (Graph 12).

The weights of 25 infants whose deaths were consecutive and occurred within three days of birth ranged from 1 lb. 6 oz. (608 gm.)

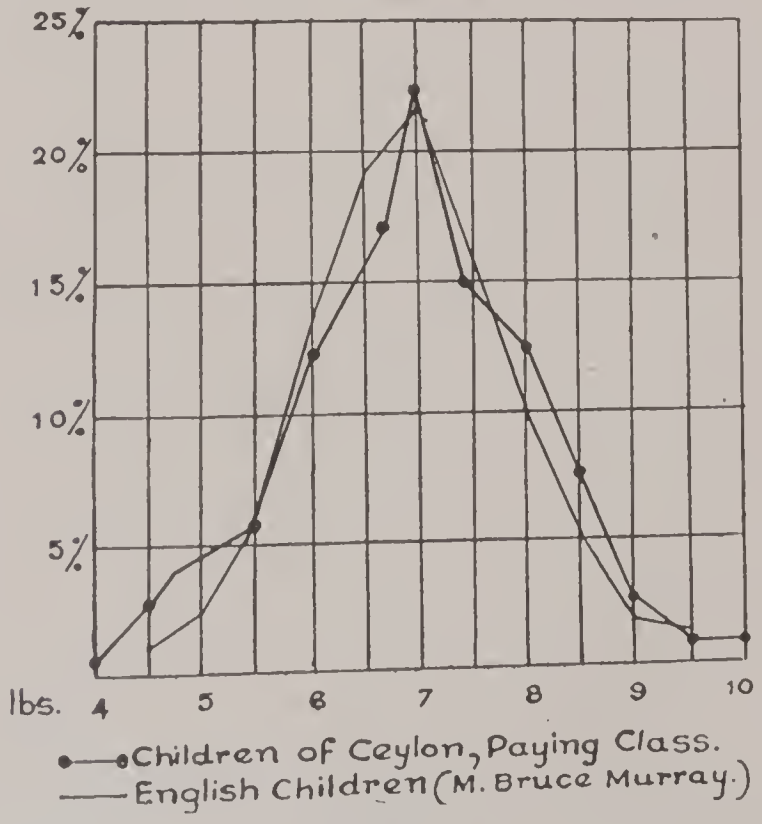
[1] The method of distribution in Graph 11 was to the nearest ¼ lb., and when the weight was midway it was placed alternatively in the higher or lower group—thus the first weight of a child of 6¼ lb. was placed in the 6½ lb. group and the next of 6¼ in the 6 lb. group.

[2] *Med. Res. Council Report Series*, No. 81.



GRAPH 11

Weights of infants at birth of two social classes compared



GRAPH 12

Weights of infants at birth of Ceylon and England compared

to 8 lb. (3,629 gm.), but the 8-lb. child was exceptional as no other weighed more than $6\frac{1}{2}$ lb. (2,949 gm.), and the average weight of these infants was 3 lb. 13 oz. (1,734 gm.).

Similarly the weights of the infants of 25 stillbirths ranged from 2 lb. (907 gm.) to $6\frac{1}{2}$ lb. (2,954 gm.), and the average weight was 3 lb. 14 oz.

Post-mortems on these infants do not reveal much to the naked eye, the only frequent sign is hæmorrhage, and the evidences are not sufficient for a definite pronouncement on the causes of death. Microscopic appearances are somewhat more revealing, there is cellular degeneration of the suprarenals and kidneys, usually fatty degeneration in the liver, and signs in all organs of past and recent hæmorrhages. There are two types of hæmorrhage—one is massive such as might be due to vitamin K deficiency, and the other is a widespread capillary exudation such as has been described by Griffith and Wade [1] as occurring in young rats on choline-deficient diets.

The vitality of infants varies with their weights at birth, and the chances of survival of those weighing less than 5 lb. are poor, especially as many of the mothers have a meagre milk secretion probably due to the same causes that produced the puny infants.

Ebbs [2] and his co-workers in America studied the influence of pre-natal diet on mother and child. The work was carried out among 400 women with low incomes. Among those on their usual poor diets 17·4 per cent. had miscarriages, stillbirths, or premature infants, whereas the percentage fell to 2·2 among a group of these women whose diets were adequately supplemented with milk, eggs and fruit.

The wealthier classes usually live under good sanitary conditions, they are free from many of the stresses of life of the labouring classes, and the ravages of hookworm infestation and malaria are less marked among them ; yet when the diets and other living circumstances of the various classes are studied it is a reasonable conclusion that the low weights of the labouring class infants, the prevalence of stillbirths and infantile deaths are mainly due to the nutritional state of the mothers.

[1] *J. Biol. Chem.*, 131, 567.

[2] *J. of Nut.*, 22, 515.

Maternal Mortality

This is high among the lower classes in most tropical countries. The vital statistics on this subject are ill-defined and unsatisfactory ; for instance, at one time the puerperal deaths in Ceylon were given as about 20 per 1,000 births, which is about five times as high as the recorded puerperal death rate for many countries of the temperate regions. But it appears that deaths from whatever cause occurring for several weeks after childbirth, and even fatalities following abortions, were included in these figures, and therefore they are not strictly comparable with the statistics from some other countries.

The causes of 273 deaths among women during the years 1932 and 1933 in the lying-in home in Colombo are given by Wickramasuriya [1] as follows :

	Per cent.		*Per cent.*
Anæmia (hookworm)	27·0	Accidental hæmorrhage	2·6
Puerperal sepsis	12·8	Post-partum shock	5·8
Eclampsia	9·8	Debility	2·2
Toxæmia of pregnancy	4·0	Infections (dysentery, pneumonia)	7·7
Pyelitis	6·6	Various other causes	15·7
Placenta prævia	5·8		100·0

It will be seen that puerperal sepsis accounted for 12·8 per cent. of the deaths, and this taking place in a well-run, up-to-date lying-in home indicates a lowered resistance of the women. The deaths from anæmia (hookworm), eclampsia and toxæmia of pregnancy together accounted for 40·8 per cent. of the deaths. All the deaths from anæmia were attributed to hookworm infestation, and some of those from eclampsia or toxæmia to this disease or malaria.

Here again are statistics which take no account of malnutrition, although almost all the women were of the indigent classes, and surveys (*vide* p. 267) have shown that the diets of these classes are deficient in more respects than one.

Hookworm infestation is exceedingly unlikely to cause the death of a well-fed woman ; and although this infestation and malaria

[1] " Malaria and Ankylostomiasis in the Pregnant Woman," *Oxford Med. Pub.*

undoubtedly played a part, yet it is probable that malnutrition had been the most salient primary cause of many of these deaths.

THE PRACTICAL APPLICATION OF NUTRITIONAL KNOWLEDGE

It is the function of the health authorities, after they have collected the necessary data of the dietary habits and practices of the various groups of a population, to initiate or point out the activities needed for the improvement of the diets in use. The diets may be considered to fall under three headings :

(*a*) *The Diets in Institutions, such as Hospitals and Prisons.* The improvement of the diets in institutions under Government or municipal control may not be a difficult matter and may be quickly brought about when the lay authorities are persuaded that good diets are a part of medical treatment, and unless they are provided the period of convalescence of the patients in the hospitals will be prolonged.

(*b*) *The Diets of Groups of Labourers.* The employers of labourers in mines, on estates, or on such constructions as roads or railways, may be persuaded that ill-nourished labourers are lazy, inefficient and have a high sickness rate, and that it is profitable to provide them with adequate diets. In some countries it will be necessary to make the provision of proper diets compulsory by law.

(*c*) *The Diets of the Population as a Whole.* This is a more difficult matter, and the improvement of the diets of the masses is not likely to be brought about very rapidly. The first need is to educate the public to the basic factors of nutrition.

Education on Nutrition

It may be accepted that the medical officers of a health department do not possess sufficient knowledge for the enlightenment of others until they have made a thorough study of local conditions by dietary and nutritional surveys. The medical practitioners of the country should be the first to be informed of the results of these surveys, circulars should be sent to them stating the inadequacies found in the diets and the possible methods of remedying them.

Next a medical officer with expert knowledge of nutrition should give lectures to nurses, sanitary inspectors and others who come into close contact with the public

Then comes the education of the public, and here efforts must be directed not only to impart the newest knowledge of nutrition in some arresting form, but also to dispel prejudices, and this may be of greatest importance. The Labrador fishermen became blind in the midst of plenty in that they threw away the livers of fish rich in vitamin A, a deficiency of which was causing their blindness. Gangs of labourers among whom beriberi was rife have refused parboiled rice because they were accustomed to raw highly milled rice. And many a labourer in the Southern States of America has suffered from pellagra because he "aint no peanut eater." All prejudices should be studied and considered sympathetically because there may be more in them than at first appears; objection to fresh milk is an instance of this (*vide* p. 239).

The proper preparation and cooking of food so that there will be little waste or destruction of the constituents must be made known and attractive methods found for cooking cheap and unpopular foodstuffs, which may have high values.

The propaganda should be carried out by medical men, district nurses and sanitary inspectors in their contact with families, and lectures with appropriate posters and lantern slides may be arranged for larger audiences. Special lectures may be given and small handbooks be prepared for school teachers. Food exhibitions may be arranged in conjunction with the agricultural authorities (see Appendix XII, p. 345). Reiterated slogans such as: "Variety is the keynote of good Dietary" and "Milk is a necessity for Health in Childhood" at lectures and exhibitions have values. Most slogans should have a pointed local appeal.

Where work has been done along the lines indicated above it has been found that the public is very receptive of information concerning its daily diets.

Popular propaganda prepares the way for the reception of special medical efforts at pre-natal clinics, maternity homes, out-patient departments and in hospitals. In these places there should be printed leaflets of the advice given to patients, because many

accept more readily that which appears in print than the spoken word.

Lecturers must always be watchful that they do not urge the use of foodstuffs which are nutritionally desirable but economically impossible.

Activities in Non-medical Walks of Life

The subject of nutrition impinges upon almost every walk of life. It is a function of the health authorities to state urgently the nutritional needs of the masses, but others must find the means for the fulfilment of these needs.

Political. Much of the malnutrition in a country is determined by the economic status of the labouring classes, and one aspect of this is an international matter, because a country may not have the means to give an adequate wage to its workers if it is in competition with another country which refuses this wage ; but international politics are far beyond the scope of this book.

A high infantile mortality rate is a disgrace to any country, and one of the many causes is malnutrition of pregnant and lactating mothers. It follows that expecting and nursing women should be adequately fed, and if they have not the means to pay for the needed foods, then the cost must be met from public funds, and this is one of many matters for local politicians. Another matter which demands their attention is the feeding of indigent school children, or possibly of all primary school children. Malnourished children are not educationally receptive, and this supports the growing opinion that a child is as much entitled to good nutrition as it is to primary education. The only argument, apart from cost, against supplying a free midday meal (or milk) in primary schools is that it curtails parental responsibility, but this is a weak argument if it comes from the wealthier classes, who delegate much of their responsibilities to servants or boarding-school masters or mistresses during the upbringing of their children.

Educational Authorities. There must be co-operation between the health and education authorities that nutritional and home-craft matters may be taught in the schools. The agricultural authorities are also concerned that wherever possible there should

be gardens near the schools where the children are taught to practise good cultivation, and learn something of the dietary values of garden produce.

Agricultural Authorities. The greater part of the food supply of most countries comes from agricultural activities. The health authorities must point out the crops which are desirable nutritionally, and the agricultural authorities should promote the production of these as far as the land is suitable for them, and they can be grown in conformity with sound agricultural policy.

In some countries there are areas where tea, rubber, coconuts, sugar and other " money " crops cover all the lands, and none is left for garden produce for the labourers, and their diets of imported foodstuffs are usually monotonous and deficient in more respects than one. There should be lands on or near all estates reserved for gardens for the labourers, and also there should be regulations for the proper cultivation of them, because instances have occurred where estate owners have set aside some lands for gardens but without provision for manure and other necessities, and these lands have become derelict.

Where food crops are grown regulations may be needed so that the local population obtain a share of them ; for estate owners or peasants have been known to sell in the best markets and leave those living in the neighbourhood without certain foodstuffs which would be of benefit to their health. Indeed there has been starvation amid plenty.

Predial larceny is so rife in some countries that the peasants will not grow fruits and vegetables which are easily pilfered. Although this may seriously affect the health of the public, yet police and magistrates are apt almost to condone this larceny under the impression that the culprits are usually in great need.

Animal Husbandry. Mixed farming is desirable not only for a supply of milk and meat but also for manure to maintain soil fertility. Unfortunately in tropical countries (except in the uplands), cattle do not thrive as in temperate climates, and the expense of supplying milk to the labouring classes may be prohibitive, especially is this the case where there are long dry seasons, or cattle disease is rife. Dried milk powders may be the only feasible

supply. The possibilities of drying milk locally during the season of plenty should always be investigated.

Goats are hardy animals and will thrive in most countries, and may contribute a much-needed supply of milk for young children.

Water buffalo cows are far more hardy, though somewhat less amenable to handling, than the common cow, and on rough pasturage will give more milk. In many wet lowlands of the tropics where the supply of milk is meagre because cattle do not flourish a greater use or introduction of the buffalo might solve the problem.

Fisheries. In no parts of the tropics have fisheries been developed to an extent comparable with the fisheries of the temperate climates. Indeed, much fish is imported into tropical countries, such as salted Canadian ling fish.

Most of the fishing takes place from the shore (the most effective method is by large seine nets) or from canoes putting out to sea. Whether or not these more or less primitive methods can be successfully replaced by the methods of temperate climates, carried out from larger boats, is a matter which has yet to be decided.

Tropical waters appear to contain fewer fish than the seas of colder climates, and added to this are the difficulties of preserving the catches. The cost of cold storage is prohibited by the price the labouring classes can afford to pay for the fish, and therefore the methods of preservation must be confined to salting, drying and smoking.

In some countries much fish is taken from the freshwater lakes and rivers, and in many cases the methods of fishing are undeveloped and uncontrolled, and this leads to wasteful practices, as when large quantities of larval fish are caught in fine cotton nets, or the whole width of a river is barred by traps against migrating fish going to the spawning grounds.

Marketing, Transport and Storage. These are matters of particular importance. It is a common experience in the tropics that some food product, which can be produced locally and is urgently needed by the masses, is not available because of the absence of the necessary marketing facilities. Co-operative marketing, dealing

with foodstuffs in small or large amounts, is proving successful in several countries.

Storage of foodstuffs in the tropics, especially where the climate is moist, presents many difficulties to overcome the ravages of bacteria, fungi and insects. Grains require to be well dried before storage. There are various small types of granaries in existence in different countries which have been in successful use from times long past. A common and successful type in use in many parts of the world is a circular structure made of such material as wattle or straw lined with clay ; it stands upon legs away from the damp of the ground and from access by vermin ; the grain is placed within and the structure sealed above with more clay, and finally a thatched roof is built over it. Doubtless with progress most granaries will be concrete structures which can be hermetically sealed and easily fumigated.

CHAPTER XVIII

FOOD POISONING

Food poisoning may be either *endogenous*, in which the food contains some naturally occurring poison, or *exogenous*, due to micro-organisms producing toxins in it.

ENDOGENOUS POISONS

1. Lathyrism

This is a spastic spinal paralysis which is usually associated with the consumption of the lathyrus pea (*Lathyrus sativus*), usually in the form of khesari dhal.

This disease has occurred in France, Italy and other countries where small peas, often in the form of dhals, may enter largely into the diets of the poorer classes. But the greatest study has been paid to widespread outbreaks in various parts of India. Acton calculated that there were about 60,000 cases in Rewah in 1922, mainly among men in the prime of life.

Anderson, Howard and Simonsen [1] carried out laboratory and agricultural studies during several years. They examined thirty samples of lathyrus peas sold in localities where lathyrism was common and found that the chief impurity in all was seeds of the weed akta (*Vicia sativa var augustifolia*). They failed to isolate poisons from the lathyrus pea, but confirmed the existence, previously reported, of the alkaloidal bases vicine and divicine and the cyanogenetic glucoside vicianin in akta. Feeding experiments on ducks and monkeys appeared to show that the lathyrus pea was harmless and nutritious, whereas akta produced types of paralysis leading to death.

Akta is a small-leafed vetch. It produces explosive pods containing seeds of various hardness, so that some germinate at the next season and some at later seasons. Hence, once the soil is con-

[1] *Ind. J. Med. Res.*, 12, 613.

taminated with this harmful weed, crops of khesari grown on the soil will be more or less heavily contaminated with akta; and special sowing and weeding are needed to get rid of it. The two seeds somewhat resemble one another, but that of akta is the smaller.

An outbreak of lathyrism has been reported in a Punjab village where *Vicia sativa* had contaminated the wheat of the previous harvest.[1]

Another aspect of the question has been reported by Young.[2] During his studies of lathyrism in a number of Indian villages he could find "no confirmation that lathyrism is caused by a contamination of *Lathyrus sativus* by the weed *Vicia sativia*." He states further: "Lathyrism is pre-eminently a famine year phenomenon, it is one of the pains and penalties of poverty and malnutrition." The villagers sow the lathyrus pea with the cereals wheat and barley, as an insurance against starvation; for with partial failure of the rains the cereals do not grow, but the pea, requiring less moisture, produces a fair crop; and then during that season khesari becomes the staple article of a diet which is deficient in many respects, especially in vitamin A. Young found night blindness common among the villagers he studied.

Mellanby [3] failed to produce degenerative changes of the nervous system of dogs by feeding them on khesari, but some samples of the akta pea readily caused these changes. Further, he found that these "lesions of the nervous system were greatly reduced by including vitamin A and carotene in the diet."

Cases of spastic paralysis closely resembling lathyrism have been reported which cannot be traced to either khesari or akta.

As pointed out by Mellanby, among samples of these peas those which have a smell of mustiness are the more poisonous, and it may be that many pulses are dangerous after damp storage.

The disease is at least five times as common among men as among women, and its onset often follows great activities; this is easily explained because the men take more food, hence more khesari, to supply the needs of hard work.

[1] *Ind. Med. Gaz.*, 74, 385.
[2] *Ind. J. Med. Res.*, 15, 453.
[3] "Nutrition and Disease" (1924), p. 140 (Oliver and Boyd).

The findings of different observers may be reconciled as follows :

(*a*) Khesari when entering largely into a generally poor diet may be followed by lathyrism.

(*b*) Akta is more poisonous than khesari and a mixture of the two is more harmful than khesari alone.

(*c*) All samples of akta and khesari are not equally poisonous, and other pulses may be poisonous or become poisonous on storage.

Pathology. Myelin degeneration of the posterior and postero-ateral columns of the cord has been described, but probably all columns are affected. Sclerosis occurs in the later stages.

Symptoms. In many cases the onset is sudden without prodromata and may follow a recent stress such as a bout of malaria. In other cases prodromal symptoms, such as tingling and numbness, occur. The earliest signs are weak, stiff and trembling legs. The severity of the symptoms rapidly increases, and in a few days the patient is unable to walk without the aid of a stick. Then a peculiar gait appears as the patient struggles to walk with the aid of a two-handed staff ; " the leg bearing the weight of the body is bent at the knee and trembles, while the advancing limb dragged wearily forward and strongly abducted, is planted unsteadily directly in front of its fellow, the toes reaching the ground first." At this stage there is no atrophy or loss of muscular tone. The knee jerks are increased, ankle clonus is marked and Romberg's sign is absent. Sensation is normal. Many patients slowly recover, but others become crippled for life.

2. Goitrogenicity of Soya Beans [1]

Rats and chicks will develop goitres when fed on preparations of soya beans. The effect is prevented by cooking ; and iodine will counteract it. The factor is not extracted by fat solvents.

3. Epidemic Dropsy

Many suggestions have been made concerning the cause of this disease. At one time, because œdema was a salient sign and the disease occurred among rice-eating people, it was customary to include it among the wet forms of beriberi.

[1] *J. of Nut.*, 22, 1.

Munro [1] had pointed out as long ago as 1908 that the lay public in India blamed mustard oil as the cause of this disease. Sarkar [2] in 1926 recorded the appearance of symptoms of epidemic dropsy in thirteen persons after the consumption of mustard oil adulterated with argemone oil. The latter oil is locally called sialkata or katakar oil and is expressed from the seeds of the prickly poppy (*Argemone mexicana*) (Fig. 20), which often grows wild in mustard fields. Mainly due to the careful work of Lal and Roy,[3] from

Prickly-poppy (Argemone mexicana.)
A. Flower + leaf. B. capsule x½. C seed x12.

FIG. 20.

1937 onwards, on the history, epidemiology and by human experiments, the cause of epidemic dropsy has become firmly established as being due to the seeds of argemone contaminating mustard seeds. Chopra [4] and his co-workers also carried out human experiments which were fairly convincing.

There are several species of mustard and the seeds of that most frequently contaminated with argemone is *Brassica juncea*. It is the edible oil expressed from a mixture of these seeds which is harmful.

[1] *Ind. Med. Gaz.*, 43, 124.
[2] *Ibid.*, 62, 506.
[3] *Ind. J. Med. Res.*, 25, 163, 177 and 239. *Ibid.*, 27, 28, 163 and 191.
[4] *Ind. Med. Gaz.*, 74, 193.

Mustard oil is widely used in India for cooking. Lal and his co-workers describe a complicated test with nitric acid by which the amount of argemone oil in mustard oil may be determined. They suggest that mustard oil containing 0·5 per cent. of the contaminant should be condemned.

Epidemic dropsy occurs at all ages, and men and women are equally susceptible. The disease is not confined to the poorer classes.

Symptoms. The onset of the disease may be slow or sudden. It usually commences with diarrhœa; vomiting may also occur. Œdema of the ankles soon appears, and may spread as far as the knees or beyond. The œdema is of a solid type and at first there is tenderness on pressure. Fever occurs in the majority of cases but is seldom high, usually ranging from 99° to 102° F. In all cases there is dyspnœa with cardiac disturbance, weak irregular pulse and low blood pressure. In some cases breathlessness and heart symptoms are very severe. The knee jerks are normal, and mild neuritis occurs only in a small percentage of cases and in these the knee jerks may be absent. The liver is enlarged.

The signs and symptoms vary somewhat in different outbreaks. In those which are not severe, intestinal disturbance, œdema, a little fever and cardiac weakness complete the picture. In more serious outbreaks erythematous rashes and pigmentation of the face occur in many cases; and in about 6 per cent. of cases curious angioneurotic nodules (sarcoids), which bleed on slight pressure, appear on the skin or occasionally on the tongue. Eye symptoms with cupping of the discs and even glaucoma occur as rarities. In some outbreaks there is marked anæmia.

Pregnant women, when affected, usually abort. The absence of neuritis distinguishes the disease from wet beriberi. The course of the disease is usually about six weeks. In some outbreaks there is little or no mortality; but in others there may be many deaths from cardiac failure.

The treatment consists in stopping the consumption of mustard oil, and giving a diet rich in proteins and vitamins. Some authors consider that a rice diet is contraindicated.

4. Atriplicism

This disease occurs in China and is due to eating the young shoots of *Atriplex littoralis*. It occurs only among the indigent. The onset is sudden with itching and tingling of the hands and later the forearms, and these parts become œdematous and the face may be similarly affected. There may be ecchymoses and bullæ aggravated by scratching. Sometimes the finger-tips become gangrenous. The disease must be diagnosed from Raynaud's disease and erythromelalgia. The œdema clears up within a week and the general health is not affected. The gangrene of the fingers leaves chronic ulcers.

5. Ackee Poisoning (Vomiting sickness of Jamaica [1])

This is due to eating a fruit, called *ackee* in Jamaica ; it is the fruit of a common West Indian and South American tree, *Blighia sapida* (Pl. X, Fig. 21). The tree was originally brought from the West Coast of Africa where the fruit is called *Isin*. The fruit is wholesome when mature and in good condition ; but unripe fruit, those from an injured branch, and many falling to the ground are poisonous. The poison of immature and unsound fruit is soluble in hot water.

Symptoms. The onset is sudden with abdominal pain and vomiting, often there is apparent recovery followed three or four hours later by very severe vomiting of a cerebral type with convulsions, coma and death. The case mortality is 80–90 per cent., and death takes place on an average in twelve hours after the onset, but the period may be as short as two hours. Convalescence is complete in twenty-four hours in those who recover.

There are no characteristic post-mortem changes. Hyperæmia of the viscera, petechial hæmorrhages of the intestine and some fatty changes in the liver are suggestive when considered with the history during life.

6. Prussic Acid (HCN) in Manioc and other Foodstuffs

Many foodstuffs contain *cyanogenetic glycosides* together with one (or more) homologous enzyme. Bruising or other injury of the

[1] The cause of " Vomiting Sickness " of Jamaica was discovered by H. H. Scott, *vide Annals of Trop. Med. and Parasitology*, vol. X.

PLATE X

FIG. 21.

ACKEE FRUIT

FIG. 22.

SECTION OF MANIOC ROOT SHOWING DETACHABLE PEEL

[*To face page* 302

foodstuff brings about enzyme action and HCN is set free from the glycoside. Cyanogenetic glycosides have been found in the following comestibles: maize, sorghum millet, rough gram (*Cicer arietinum*), field bean (*Dolichos lablab*), lima bean (*Phaseolus lunatus*), black gram (*P. mungo*), kidney bean (haricot) (*P. vulgaris*), sweet potato (*Ipomœa batata*), manioc (cassava) (*Manihot utilissima*), lettuce (*Lactuca sativa*), linseed (*Linum usitatissimum*), almond (*Prunas amygdalis*), lemons, limes, cherries, apples, apricots, prunes, plums and pears.

In most of the above foodstuffs the glycosides are never likely to give rise to poisoning either because they are present in very small amounts, or occur in parts which are not eaten, such as in the seeds of fruits, apple pips for instance.

The first glycoside to be isolated was *amygdalin* from bitter almonds, and it has since been found in apricots, plums, pears and other fruits. Emulsin of almonds hydrolyses this glycoside to benzaldehyde, HCN and glucose as in the following equation:

$$C_{20}H_{27}O_{11}N + 2H_2O = C_7H_6O + HCN + 2C_6H_{12}O_6.$$

The emulsin of almonds consists of three enzymes—amygdalase, β-glucase and cyanase—and the process of hydrolysis takes place in three stages.

Dhurrin is the glycoside of the sorghum millet.

Linamarin is the glycoside of linseed, beans, peas and manioc (cassava). The enzyme which frees the HCN is linase.

Manioc and HCN. There are two cultivated species of manioc (*M. utilissima* and *M. palmata aipi*), the latter is called "sweet manioc." There are many races of these species, and although they all produce and store a cyanogenetic glycoside yet some races produce much more of the poison than others.

Nature has placed most of the glycoside and enzyme in the outer coats of the manioc root, apparently as a protection against insect pests. These outer coats form a peel which is easily removed (Pl. X, Fig. 22).

When the content of HCN is being determined the peel and the rest of the root are separated, smashed up and allowed to stand for two hours, this liberates the enzyme which in its turn breaks up the glycoside and frees the HCN (*vide* Appendix XIII, p. 353).

Analyses of samples of ordinary garden manioc shows that on an average the peel contains about 0·1 per cent. HCN and the rest of the root only 0·003 per cent.

The smallest dose of HCN known to have been fatal for an adult is 0·9 grains (0·06 gm.), but recovery has taken place after 2·4 grains. The peel constitutes about 20 per cent. of the whole root. It follows that about 2 oz. of the peel or 10 oz. of the whole root of an average sample of well-bruised manioc contains a minimum fatal dose. Some roots, however, are far more poisonous than this.

Fresh, healthy and undamaged roots freed from the peel are seldom poisonous, but in bruised or otherwise damaged roots the liberated HCN of the peel spreads throughout the whole root.

Symptoms of Poisoning. These start suddenly with giddiness, headache and mental confusion followed by insensibility and loss of muscular power. The eyes are bright and prominent. Breathing becomes stertorous and death takes place from asphyxia. Convulsions and involuntary urination and defæcation often precede death. Vomiting may occur. Death usually occurs within two hours of taking the meal, but the fatal period may be longer.

Much discussion has taken place on the question of chronic or cumulative poisoning, but the evidence is against the existence of these. General ill-health, however, may be the result of repeated attacks of sub-acute poisoning.

Post-mortem Signs. These are suggestive of death from asphyxia. But most reliance must be placed on the presence of large quantities of manioc in the stomach, smelling more or less strongly of HCN.

Treatment. The best antidote is a mixture of ferrous and ferric salts with a strong alkali such as sodium carbonate. This should be followed by washing out the stomach and repeating the dose.

Precautions when Cooking Manioc Roots:

(1) Manioc roots should not be bruised, and damaged roots should be discarded.

(2) The roots should be as fresh as possible and not exposed for long to the sun.

(3) The roots should be peeled and quickly washed. The cooking pot should not be more than half filled with the peeled roots.

(4) The level of the water in the vessel should always well cover the roots so that steam will not condense on exposed roots and fall back into the pot.
(5) The vessel should not be covered with a lid so that the volatile HCN may escape with the steam.
(6) The water in which manioc has been boiled must be thrown away.

Some people who are accustomed to eat much manioc will not take uncooked food with it. There may be a sound reason for this, in that the enzymes are destroyed by cooking, and HCN is no longer set free from the glycoside in boiled manioc; but the enzymes of fresh vegetable foods may be able to act on the glycoside in the stomach or intestines.

Lima Beans (*P. lunatus*) and HCN

The amount of HCN in these beans varies greatly; in analyses of ten samples grown in different localities the amounts ranged from 0·1 to 0·006 per cent. The beans have diverse colours or combinations of colours, such as red, brown, white, red on buff, etc., but the colour of a sample is not a criterion of the quantity of poison it contains. Usually, however, the white beans do not contain more than 0·02 per cent.

Lima beans are far less likely to cause poisoning than manioc; one of the reasons is that the enzyme can act only to a limited extent in the dried bean, and when cooking takes place boiling quickly destroys the enzyme.

7. Selenium Poisoning

There are limited areas scattered widely throughout the Great Plains of the U.S.A. and other parts of the Americas where the soils contain an unusual amount of selenium. The fodders and grains grown on these soils are unduly rich in selenium, and poisoning occurs among the farm animals of these areas.

The poisoning was first called "alkali" disease because it was thought to have some association with patches of alkaline soil. The disease has also been called *blind staggers*.

The signs in cattle are stunted growth, emaciation, loss of hair,

the hooves are affected and in severe cases there is even shedding of the horn of the hoof, atrophy and cirrhosis of the liver, extreme anæmia and death. Reproductive power is diminished. Fowls fed on seleniferous corn produce eggs which are infertile when the grain contains 10 parts per million, of low hatchability at 5 p.p.m., but are not affected at $2\frac{1}{2}$ p.p.m.

Young rats are very sensitive to selenium and if fed when 3 weeks old on wheat grown on seleniferous soil they will die in about 20 days, whereas older rats similarly fed are not greatly affected.

High protein diets are protective if they are rich in methionine, for it appears that one of the poisonous effects of selenium is to inhibit enzymes which depend for their activity on sulph-hydryl groups.

The serious effects which are seen in cattle have not been found occurring in people living on seleniferous land. The reason is that human beings in proportion to their size consume far smaller amounts of foodstuffs than farm animals ; and also much human food may be imported and not grown in the locality.

Mild selenium poisoning in human beings causes stunting of growth, loss of appetite and gastric and intestinal disturbances.

The selenium in plants grown on seleniferous soil can be reduced by manuring the soil with large quantities of sulphur and calcium sulphate.

The determinations of selenium in biological materials are complicated procedures.

8. Molybdenum

There are pastures in Somersetshire called " teart " lands, where sheep suffer from diarrhœa and wasting, due to molybdenum in the fodder. For some unknown reason the administration of copper will cure the condition.

9. Fluorosis

Mottling of the teeth was the first recognized result of chronic fluorine intoxication. This condition, reported from many parts of the world, is usually due to the presence of fluorine in drinking water. When the amount of fluorine in the water exceeds one

PLATE XI

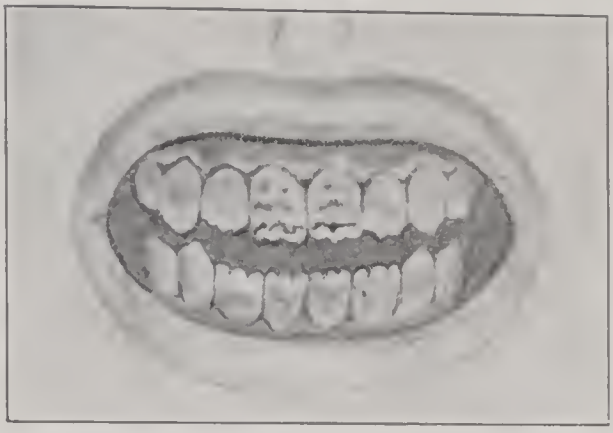


FIG. 23.

FLUOROTIC TEETH

FIG. 24.

FLUOROSIS OF TIBIA

[*To face page* 307

part per million some degree of mottling of the teeth usually occurs among the children drinking it.

The permanent teeth are much more often affected than the deciduous, but where the fluorine content of the water supply is particularly high the latter may also show mottling.

The sequence of change is that areas of the enamel slowly lose their shiny appearance and become dead white, resembling chalk ; these areas may be irregular patches on the surface in the centre of the teeth, or may appear as bands or irregular striations. These white areas become irregularly pigmented to a chocolate colour, so that white opaque areas and other areas of various degrees of pigmentation give the teeth a marked mottled appearance. These changes are commonest in the upper incisors, but any teeth may be affected.

Hutchinsonian teeth (Pl. XI, Fig. 23) of the lower jaw are sometimes seen in cases of fluorosis in children whose sera are negative to tests for syphilis ; but they also occur in malnourished children who are neither fluoritic nor syphilitic.

Observations that fluorotic teeth are somewhat resistant to caries have received support from animal experiments which show that fluorine reduced the incidences of caries in rats fed caries-producing diets.

Far more serious conditions than fluorotic teeth may occur in persons who ingest relatively large quantities of fluorine. Cryolite is a naturally occurring sodium aluminium fluoride and it is used in several manufacturing processes, such as in the production of aluminium or making opal glass. Roholm (1937) [1] described chronic fluorine intoxication among cryolite workers in Denmark, and recorded calcification of ligaments and increased density of bone leading to stiffness, limitation of movement accompanied by aches and pains.

Shortt [2] and his associates studied endemic fluorosis in the Madras Presidency in localities where the drinking water contains 2–3 p.p.m. of fluorine and in some places more than this. Serious intoxication apparently does not occur much before the age of

[1] " Fluorine Intoxication," Lewis & Co., London.
[2] *Ind. J. Med. Res.* (1937), 25, 553 ; and *Ind. Med. Gaz.*, 72, 396.

thirty, nor with less than fifteen years' consumption of fluorotic water and then slow calcification starts. X-ray photos of the affected show that the skeleton increases in density and osteophythic outgrowths appear on various bones, such as the long bones, vertebræ and ribs. Many ligaments and even fasciæ become calcified (*vide* Pl. XI, Fig. 24). These changes cause severe rheumatic pains, rigidity of the spine, limitation of movement of the joints and thorax. The patient must turn his whole body when changing the direction of his gaze. The joints and limbs first affected may be those on which occupational stresses fall, for example, more strain falls upon the left than upon the right arm of basket makers, and their left wrists and arms are the first to show the effects of fluorosis. Calcification of thoracic structures leads to fixation of the chest and diaphragmatic breathing. In extreme cases the patients may eventually become bed-ridden. Mottled and striated finger nails have been described as an early sign of fluorosis by Leo Spira.[1]

Pandit [2] and his co-workers studied the incidence of fluorosis in the Madras Presidency in conjunction with dietary surveys, and reported that malnutrition was a contributory factor in the production of mottled teeth ; and further that avitaminosis C played an important part in bringing about the skeletal changes. Pandit and Rao [3] produced marked increase of skeletal density and osteophytic outgrowths by administering sodium fluoride to monkeys on diets deficient in vitamin C.

In localities where the rocks are relatively rich in fluorine not only water but also foodstuffs may be contaminated with the element, and this may add to the amount taken in with the water. But, strangely enough, fluorosis appears never to have been traced to foodstuffs alone although they may contain considerable amounts of fluorine. Reid [4] has shown that Chinese teas may contain 3·75–39·88 mg. per 100 gm. on a dry basis. Lockwood [5] has found similar high amounts of fluorine in Chinese and Indian teas.

Determination of Fluorine in Water. Various methods have been used and the simplest is Sanchis, which has the advantage that it can be used in field work (*vide* Appendix XIV, p. 354).

[1] *J. of Hyg.*, 43, 69.
[2] *Ind. J. Med. Res.* (1940), 28, 533.
[3] *Ind. J. Med. Res.*, 28, 559.
[4] *Chinese J. Phys.* (1936), 10, 259.
[5] *Analyst* (1937), 62, 775.

Treatment of Fluorine Water. The fluoride ions in water can be removed by filtration after they have been precipitated by such chemicals as alum, lime or magnesia, but the processes are far too expensive for large water supplies.

Various mixtures of more or less insoluble chemicals, which will remove the fluorides when the water comes in contact with them, have been used. Most of them contain large amounts of aluminia, and they are placed in the sand filter bed. *Defluorite* prepared by Jewell Filter Co. is one of these. The disadvantage is that most of these preparations are quickly exhausted and hence are expensive.

10. Saponins in Foodstuffs

Saponins have been found in many foodstuffs, and among these are : soya bean, beetroot, palmyra root (*Borassus flabellifer*), potato, tannia (taro) (*Colocasea*), alfalfa (*Medicago sativa*), spinach (*Spinacea oleracea*), trianthem (*Trianthema monogyna*), bread fruit, tomato, pumpkin (*Cucurbita maxima*), calabash (*Lagenaria vulgaris*), ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia*), ground nut (*Arachis hypogœa*), capsicum, melon, orange and rambutan (*Nephelium lappaceum*).

The saponins are a somewhat heterogenous group of nitrogen-free glucosides, and many of them, though not all, have the general formula $C_nH_{2n-8}O_{10}$. The name saponin is derived from their property of forming frothy soap-like solutions in water. On hydrolysis they break up into glucose and substances having the general name *sapogenin*. Many of them are difficult to isolate.

Not all saponins are poisonous, and the most poisonous have been somewhat loosely called *sapotoxins*.

Some sapotoxins have no effect on the alimentary tract and are not absorbed from it, and hence may be swallowed without harm. Cyclamen (sowbread, *Cyclamen Europeum*) contains a sapotoxin very poisonous when injected, yet pigs will feed and thrive on cyclamen. It is, however, a drastic cathartic for man.

Other sapotoxins are easily absorbed from the alimentary tract—that of the corn cockle (*Argostemma*) is an example. It has been suggested that some cases of mysterious poisoning have been due

to the accidental contamination of wheat or other cereals with the seeds of the corn cockle.

It is possible that sapotoxins which are not absorbed from the healthy alimentary tract may be absorbed when there is ulceration.

Dr. Alfred Clark,[1] working in Trinidad, attributed the prevalence of nephritis among the labouring classes to the great consumption of the coco-yam tannia; the suggestion being that it was due to the irritant action of the saponin. Oberdorffer[2] considered the consumption of coco-yams (*C. antiquorum*) in Nigeria a predisposing factor in the spread of leprosy. But the evidence in both cases is far from conclusive.

Sapotoxins are general irritants, and when rubbed into the skin cause inflammation and bleb formation. When taken by mouth they may cause severe gastro-enteritis, and on absorption form compounds with lecithin and produce paralysis of the nerve centres and the heart. Nothing is definitely known of chronic or cumulative poisoning in man.

11. Solanin

This, occurring in potatoes, is allied to the saponins. The amount in potatoes depends on various factors such as the condition of the weather during growth. Potatoes which have been partly exposed and have become green contain an increased amount of solanin and large potatoes contain more than small ones.

About 30 mg. per 100 gm. of solanin must be present in the roots before poisoning is likely to occur.

The symptoms of poisoning are those of acute gastro-enteritis associated with nervous prostration and collapse resembling those caused by poisonous fungi.

Potatoes sometimes become poisonous after improper storage has allowed sprouting to occur. There is some evidence that this is due to bacterial invasion of the roots.

12. Poisonous Fungi

Many relatively large fungi of the class Basidiomycetes are edible and are called in a generic sense *Mushrooms*. A few species are poisonous.

[1] *Trans. Roy. Soc. Trop. Med. and Hyg.* (1932), **26**, 301.
[2] *Arch. f. Schiff-v. Tropen-Hyg.* (1938), **42**, 367.

The symptoms of poisoning by these fungi may be mainly gastro-intestinal with vomiting and purging, or mainly cerebral with excitement, convulsions, delirium and stupor, or a mixture of the two. The pupils may be dilated or contracted, depending upon the particular species of " mushroom " consumed ; if it contained *muscarine*, then the pupils will be contracted.

The treatment consists in emptying the stomach, stimulants, warmth and, if the pupils are markedly contracted, the administration of one-fiftieth grain of atropine.

13. Bread Poisoning

This has occurred where the wheat or other cereals has been largely contaminated with the seeds of some poisonous weed. In the few cases reported the corn cockle, darnel grass (*Lolium temulentum*) or one or other species of Senecio has been suspected. In the case of the latter it has been suggested that the seeds are poisonous because of infection with the fungus *Endoconidium temulentum*, but this is doubtful.

Bread poisoning cannot occur where the wheat is properly cleaned of foreign matter prior to milling. But the wheat is seldom properly cleaned where primitive village methods are in use for preparing flour.

Ropy bread is not poisonous but may give rise to digestive disturbances. It is due to infection of flour, kneading troughs or other part of the bakery with the spore bearing anærobe *B. mesentericus* (*panis viscosi*). Great cleanliness in the bakery is needed for its elimination.

14. Fagopyrism

All parts of the buckwheat plant (*Fagopyrium esculentum*) contains a substance capable of producing photo-sensitization in animals. This occurs only in stock having unpigmented skin and after exposure to the sun, when a vesicular dermatitis occurs.

Some human individuals are sensitive to buckwheat and develop a rash after eating foods made from buckwheat flour.

15. Fish Poisoning

Symptoms of gastro-enteritis following the consumption of fish, especially when stale or tinned, are usually due to exogenous poisons produced in them by bacteria after the fish have been caught (*vide* p. 312), but some fish contain endogenous poisons about which little is known. These may be considered under three headings :

(*a*) A few individuals have an idiosyncracy to "shell fish" (crabs, lobsters, molluscs, etc.), and consumption of these may be followed by digestive disturbances more or less severe, or by general malaise and urticaria.

(*b*) Fish of some genera always contain potent poisons. In most cases the poison is confined to some particular organ. Death has followed the consumption of roes of fish of the genus Tetradon (Parrot fish), but if the fish are gutted when caught the flesh is harmless.

The livers of many of the *Porcupine fish* (Diodon) contain a deadly poison, and when they are eaten death may occur within an hour.

The usual symptoms are gastro-enteritis quickly followed by generalized poisoning leading to delirium and coma.

(*c*) Fish, which may usually be eaten with impunity, become poisonous in some localities at certain seasons. This has been known to occur with many kinds of shell fish (crustaceans and molluscs) and even with such common fish as eels, mackerel, herrings, sprats and barracuda (*Sphyræna*). The reason of the appearance of these poisons in fish is not known, it is probably due to the fish consuming poisonous foodstuffs.

EXOGENOUS POISONS

Bacterial Food Poisoning

The term *ptomaine poisoning* has been so widely used that the origin and meaning of it is worth while considering.

Selmi gave the name *ptomaine* (from the Greek word meaning a carcase) to certain substances found in putrefying meat, and having some chemical reactions similar to those of vegetable alkaloids.

They contain amine groups and are formed by bacteria splitting off CO_2 from the amino-acids of proteins, thus :

$$\underset{\text{ornithine}}{CH_2NH_2.(CH_2)_2.CHNH_2.COOH} = \underset{\text{putrescin}}{CH_2NH_2.(CH_2)_2.CH_2NH_2} + CO_2$$

$$\underset{\text{lysine}}{CH_2NH_2.(CH_2)_3.CHNH_2.COOH} = \underset{\text{cadaverin}}{CH_2NH_2.(CH_2)_3.CH_2NH_2} + CO_2$$

It will be seen from the above formulæ that ptomaines are strongly basic.

Mainly due to the work of Brieger,[1] from 1889 onwards food poisoning came to be regarded as due to ptomaines appearing in food as the result of bacterial decomposition. But putresin, cadaverin and the great majority of ptomaines which have been isolated, are not poisonous in the amounts occurring in putrefying food. Further ptomaines appear only in foods in a state of decomposition far too repulsive for human consumption.

The belief in ptomaine poisoning disappeared among bacteriologists as the result of the work of Savage and White [2] in England and Jordon [3] in America. These investigators found that most outbreaks of poisoning were due to the infection of food with organisms of the *Salmonella* group, and much more rarely to other organisms. The former workers mention four outbreaks due to bacteria of the dysentery group.

Dack [4] and his colleagues in Chicago have found that food poisoning may be due to toxins generated in foods by certain staphylococci. This has been confirmed. Streptococci have been incriminated in a few cases.

Botulism, a rare and special type of food poisoning, was well known in the last century, and the causal organism was isolated and incriminated by van Ermengem in 1896.

Therefore the vast majority of all cases of bacterial food poisoning fall into one or other of the three categories :

(*a*) Salmonella poisoning.

(*b*) Staphylococci poisoning.

(*c*) Botulism.

But, as several of the organisms of the Salmonella group cause

[1] *Virchow's Arch.*, 115, 483.
[2] *Spec. Rep. Series Med. Res. Coun.* (1925), 91, 92.
[3] "Food Poisoning," Univ. Chicago Press.
[4] *J. Prev. Med. Baltimore* (1931), 5, 391.

enteric infections of the paratyphoid type it is advisable to consider the limitations of the significance of term *bacterial food poisoning*.

In some cases all the signs and symptoms are produced by toxins generated in the food by the particular bacteria or set free from the bodies of the bacteria by digestion in the alimentary tract. The following laboratory accident is an example of this: Researches were being carried out on the effects of dysentery vaccines given by the mouth. A flask of sterile milk had been inoculated from a culture of *B. flexneri*, incubated for 48 hours, and sterilized by heating to 60° C. Its sterility had been confirmed culturally. The odour and taste of the milk were indistinguishable from boiled milk. A inquisitive laboratory attendant drank about 2 oz. of the milk from this flask; in a few hours he became seriously ill with vomiting and the continual passage of blood and mucus; he died in 24 hours. This fulminating attack was due to the endotoxins of masses of *B. flexneri* being set free in the intestines.

On the other hand there may be a subsequent infection imposed upon the initial poisoning. The following is an example of this: Many cases of dysentery of sudden onset occurred on a large ocean liner; the outbreak started in the Red Sea and several persons had died by the time the ship reached Ceylon. Cases had occurred among the first- and second-class passengers and the crew, and as there were three separate kitchen galleys, the only prepared foodstuffs common to all on board were bread, butcher's meat and milk. The milk supply was quickly incriminated. Reconstituted milk was in use, it was prepared by mixing in hot water correct amounts of dried skimmed milk powder and fresh butter from the cold storage and shaking thoroughly. Customarily this was done in a machine called the "iron cow," which could be kept more or less sterile; but the iron cow had broken down and the milk was being prepared by a youth detailed to shake up the mixture in large bottles. The youth was found to be a chronic carrier of *B. flexneri*, the organism was isolated from his fæces. He stated that he had suffered from dysentery on the previous voyage. The cases ranged from mild to fulminating attacks of dysentery; the severity, doubtless, was determined by the amount of *B. flexneri* swallowed.

The term food poisoning should be used only for those cases where the signs and symptoms appear within a few hours of the consumption of the infected food and are due to bacterial toxins. But when there is an incubation period of a day or more followed by more or less prolonged fever, the disease is an infection. It follows that in the case of some organisms food poisoning and infections may occur in the same outbreak as was the case in the second example mentioned above.

Salmonella Poisoning

A very large number of species of the Salmonella group have been incriminated in food poisoning. *S. typhi-murium*, previously named *S. ærtryche*, is by far the commonest, it has been found in 60 per cent. of outbreaks of salmonella poisoning in Great Britain. It is followed in frequency by *S. choleræ-suis*, *S. enteritidis* (*Gærtner*), *S. thompson* and *S. newport*.

Poisoning by these organisms falls into two types. The first is due to the toxins only, generated in stale food ; the onset is sudden with acute vomiting and diarrhœa, which as a rule subside suddenly and complete recovery takes place in a day or two ; deaths from this type of food poisoning are rare. The second type is usually more serious, it starts with sudden onset due to toxins, but the disease continues due to the invasion of the toxin-damaged mucosa of the intestines by the organisms, and an enteric fever of varying severity sets in.

There are two important facts which should be remembered in connection with salmonella food poisoning :

(1) That the organisms may generate much toxin in a food without producing a taint discoverable by tasting or smelling.

Topley and Wilson [1] (p. 1,260) illustrate this with a graphic story told by van Ermengem. A meat inspector in Belgium was asked to give his opinion on some suspected sausages. Judging from their excellent appearance, their good smell and their rosy colour he pronounced them suitable for consumption, and to show their harmlessness he ate three slices himself. He developed acute gastro-

[1] " The Prin. of Bact. and Immun.," Ed. Arnold and Co., London.

enteritis and died in five days. From his viscera at autopsy and from the sausages, *S. enteritidis* was isolated.

(2) Although the organisms are easily killed by heat the toxins of some of them are not destroyed by ordinary cooking.

Salmonella poisoning is probably the commonest form of bacterial food poisoning. Savage and White state of outbreaks they investigated : " Excluding three outbreaks probably not food poisoning and including one cheese outbreak as certainly of Salmonella origin, this gives 67 out of 97 or 70 per cent. of food poisoning outbreaks as due to Salmonella bacilli."

Staphylococci Food Poisoning

This is a gastro-enteritis due to the consumption of foodstuffs in which very heavy growths of certain strains of staphylococci have occurred. Most outbreaks have been traced to ice-creams, milk, pastries, cakes or other confectionery which have been kept under conditions favourable for bacterial growth. Ice-creams prepared for some time prior to freezing, or old stock, which has thawed and been frozen again, have been incriminated on many occasions.

Staphylococcus albus, aureus, and even a yellow type have been found in foods causing outbreaks of poisoning. But many strains of these three types appear to be harmless.

Staphylococci are ubiquitous organisms, and the isolation of any of them from food is no indication that the food is harmful ; before any can be considered harmful the organism must be found in heavy growth. There is no satisfactory animal test of their toxicity ; but when 0·5 ml. of a broth culture of a harmful strain is heated to 100° C., quickly cooled and injected intraperitoneally into a guinea pig it is usually followed by severe enteritis.

Botulism

This is due to the toxins produced by the anærobe *Clostridium botulinium* in foodstuffs. The organism is common in soils and can be isolated in nearly 30 per cent. of all samples. Hence many foodstuffs are naturally contaminated with its resistant spores. But the organism is not pathogenic in the sense of being infective, and can produce toxins only under very special circumstances.

Most cases of botulism in Europe have been traced to sausages,

hams, game *pâtés*, potted meats and bacon. Whereas in America the commonest contaminated foods have been canned fruits and vegetables, string beans, spinach and beans. Cheese, and dried or salted fish have also been incriminated.

The spores of C. botulinium in a neutral medium may resist boiling for several hours or a temperature of 120° C. for 20 minutes. It is strange therefore that much canned or bottled foodstuff prepared in home kitchens does not become dangerous. The manufacturers of canned foodstuffs are alive to the dangers, and order their methods of sterilization to meet them.

The organism is a gas former, and in most cases of infected canned foods the cans are *blown*; that is, they bulge and gas escapes on opening them.[1] The food may have a rancid smell and a disintegrated appearance. Unfortunately, cans with toxic foodstuffs are not always blown, and the contents may appear to be satisfactory.

The incubation period is usually less than twenty-four hours after consumption of the affected food, and rarely it may be prolonged to the third day. There may be vomiting, but most of the symptoms are referable to the nerves, the eyes show paralysis of accommodation, diplopia and ptosis; there is dysphagia, aphasia and diminished secretion of saliva. The temperature is generally subnormal. When death occurs it takes place with great suffering; the patient remains conscious but cannot speak, see or swallow and the respiratory movements become gradually paralysed.

It is stated that oils prevent the absorption of the toxin, and that soaps neutralize the toxin, and therefore vegetable oil by mouth and high soap enemas are recommended for treatment.

Outbreaks of Food Poisoning

The nature of the foods which give rise to bacterial poisoning differ in different countries, sausages are a common vehicle in Germany, canned vegetables and fruits in America, and various types of fresh, dried or salted fish in many tropical countries.

[1] Other organisms than C. botulinum may be the cause of blown cans. Sometimes the contents of blown cans are sterile, when this occurs it may be due to cans containing acid vegetables or fruits, and having cheap perishable linings (such as shellac), and CO_2 is produced when the acids come in contact with the underlying metal.

Savage and White gave the nature of the vehicle in 203 outbreaks as follows :

	Number	*Per cent.*
Canned meat	31	30·5
Canned fish	27	
Canned fruit	4	
Milk	14	6·9
Milk products (cheese, ice-cream, etc.)	16	7·9
Made up meat (potted meat, sausages, brawn, etc.)	54	26·6
Manipulated meat (pickled beef, frozen meat, etc.)	10	4·9
Butcher's meat	33	16·3
Fruits and vegetables (tomatoes, plums, potatoes)	8	3·9
Other foods	6	2·9

Outbreaks of food poisoning are common in hotels and boarding houses in the tropics, and are particularly common on ships plying in tropical waters, the reason in the latter case is easily explained. The space which can be allotted for a ship's galleys is necessarily small, the cooks and other workers are much more crowded together than those doing similar work on shore. The temperature in the galleys may be very high, in fact, it may be above blood heat, and perspiration drops from the cooks and contaminates the dishes they are preparing. When there are rough seas an increased strain is thrown upon the workers in the galley ; liquid food will inevitably be spilled or splashed on the benches, in the cold lockers and on the decks ; solid food may roll off pans and dishes. This soiling supplies an excellent pabulum for bacteria, and when rough weather continues for several days there will be difficulty in cleaning the galleys, and the heat will be conducive to a rapid growth of bacteria. The brushes and mops may become infected and distribute the infection, so that once an organism of the Salmonella or other group establishes itself it will become widespread and multiply in any food which is favourable for its growth. Such infections usually last for many voyages. The original infection may have been brought on board in any foodstuff, or it is possible that there may be a " carrier " of some particular organism among the galley crew.

The prevention of food poisoning requires the practice of scrupulous cleanliness in kitchens and galleys. All benches, sinks, vessels and appliances used in the preparation of foods should be scalded

with boiling water after use. Particular attention should be paid to the milk supply. Brushes and cloths used for cleaning should be boiled periodically. A limit should be placed on the number of times any food, such as a joint, is removed from and returned to cold storage. Ice-creams which have been thawed and kept for some time at room temperature and stale pastries should be discarded. Dishes made from remnants should be avoided as far as possible. It should always be remembered that cooking may not render a contaminated food safe.

Food Poisoning by Infective Fungi

Ergotism is due to cereal grains being attacked by the ascomycete fungus *Claviceps purpurea*. Most outbreaks have occurred in Europe and Asiatic Russia. Rye has been the commonest grain attacked.

The fungus grows in the grains, which enlarge and become replaced by the Mycelium. Finally a large purple black, hard mass known as the *sclerotium* is formed. This is the poisonous ergot grain. Bad weather conditions and water-logged soils predispose cereals to the attack of this fungus.

The disease occurs in two types : (*a*) *Gangrenous ergotism*, where the poison mainly affects the arterioles, causing thickening of the middle coat and hyaline degeneration of the intima, and this leads to thrombosis. The result is gangrene of the toes and fingers and occasionally of the ears and tip of the nose. (*b*) *Convulsive ergotism*, where degeneration of the posterior columns of the spinal cord and cells of the brain occurs. The disease starts with numbness and formication of the hands and feet, with twitchings and cramps of the muscles of the fingers and toes. Later the muscles of the whole body are affected.

The patient may tumble about in a drunken manner from extreme giddiness. Convulsions, blindness and deafness are more advanced symptoms and there may be delirium. Relapses are sometimes accompanied by hemiplegia or paraplegia.

Mellanby has shown that ample vitamin A or carotene protects dogs and rabbits against poisoning by moderate doses of ergot. So here again, as with lathyrism, deficient diets are the predisposing cause of outbreaks of the disease.

The treatment consists in giving a generous diet particularly rich in vitamin A.

Claviceps paspali infecting the seeds of grasses of the genus *Paspalum* has caused poisoning, similar to ergotism, in horses and cattle. It is possible that infection of the millet *Paspalum scorbiculatum* might cause poisoning in man. And it may be that other fungi of this genus have yet to be recognized.

CHAPTER XIX

INSECT PESTS OF CEREALS AND PULSES

SEVERAL hundred species of insects have been recorded breeding in grain foods or the products of grain foods. A few of them are common, very destructive, and range widely throughout the tropics. Some are nearly cosmopolitan.

They may be conveniently, though roughly, placed into three categories :

(1) Weevils, which can breed only in grains and not in flours or meals.
(2) Small brown flour beetles.
(3) The larvæ of small moths (*microlepidoptera*).

Weevils

The *rice weevil—Sitophilus* (*Calandra*) *oryzæ* (Fig. 25) is about 3·5 mm. long. The rostrum is about two-thirds the length of the thorax. The anterior end of the thorax is slightly constricted and lobulated. It closely resembles its more widely studied relative *S. granarius*, of temperate climates, from which it can be distinguished by the shape of the thorax, a minute pit between the eyes at the base of the rostrum and well-developed wings.

Life History. It will breed in any cereal grain. Each egg is laid in a hole bored in a grain, the opening is sealed with a gelatinous substance. It lays about five eggs a day. A single female may lay 200 or more eggs. The larva hatches out in a few days, and as it feeds it tunnels through the grain and discharges a considerable amount of frass. When full grown the larva pupates within the grain. It develops most rapidly when the moisture in the grain is 12–14 per cent., and develops slowly when the moisture is only 8 per cent. Under favourable conditions of moisture and temperature the entire life history is about one month. It will be realized from this that in a heavily infested granary two or three generations of weevils can destroy an enormous amount of grain. This weevil ceases to breed at 88° F.

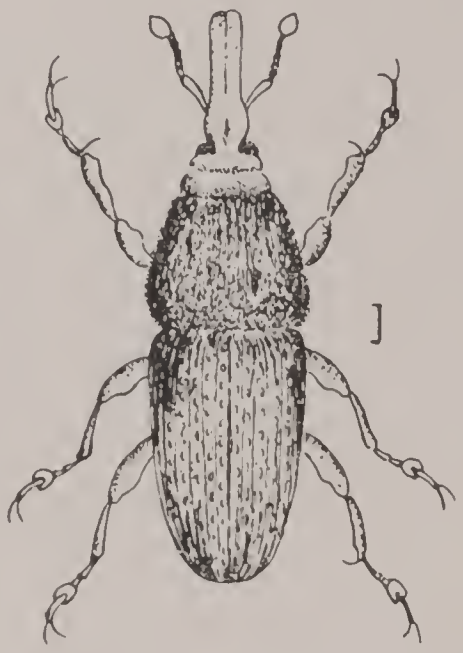
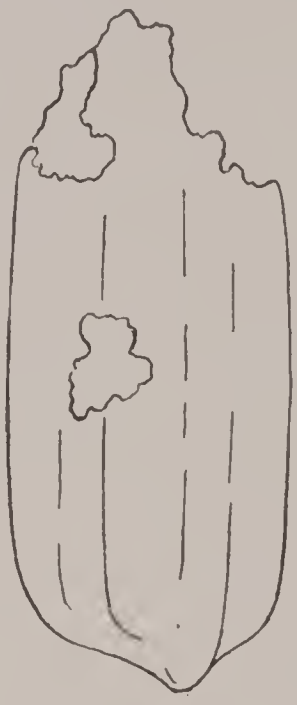


FIG.25 Calandra oryzae



Rice grain
after infestation.

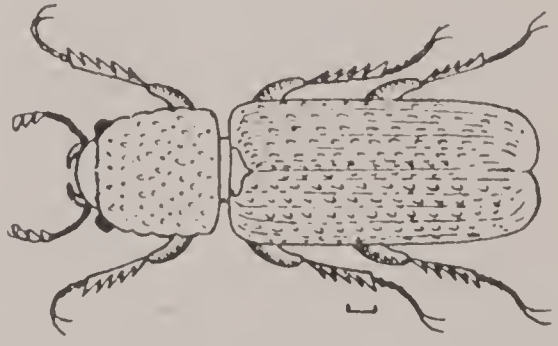


FIG.26 A Rhizopertha dominica

FIG.26 B Rhizopertha dominica.
(Side view.)

The common weevil—Sitophilus (*Calandra*) *granarius* is far less common in the tropics. It can breed in biscuits, macaroni and caked flours as well as any cereal grain. The wings are rudimentary and useless for flight.

The lesser grain weevil—Rhizopertha dominica (Fig. 26, A and B) is a small, very active brown beetle of about 4 mm. in length, The head is characteristically bent down and partly concealed by the thorax. The antennæ are prominent with three enlarged terminal segments turned inwards. The thorax is dome shaped with crenulate margins. The dorsum has many punctations, those of the elytra being arranged in lines. Where a granary is infested large numbers may be seen flying about.

Life History. The eggs, 0·6 mm. in length, are laid singly or in clusters among the grains. The number of eggs laid by each female is 300–550 at the rate of 20 a day. The incubation period ranges from 5 to 30 days according to the temperature. The larva at first has difficulty in penetrating the grains and lives on frass until after the first moult; it then enters a grain and during growth moults three times and then pupates. The length of the life history ranges from twenty-four days to several months, depending on the temperature. There may be five generations in a year in tropical climates. It can breed at higher temperatures, and withstand dry conditions better than the rice weevil. It has been found breeding in wheat, rice, barley, peas, beans and army biscuits.

Pea Weevils. These belong to the family *Bruchidæ* and there are several hundred species of them. They are all short squat beetles with long antennæ, usually serrated. When dead the head is usually bent against the under surface of the thorax. A marked characteristic is that the elytra do not extend to the end of the abdomen, so that the end segments are exposed.

Bruchus pisorum, a common pea weevil, is shown in Fig. 27. Perhaps the commonest pea weevil in India is *B. chinensis*, it can be recognized by its long very serrate antennæ. It causes the destruction of large quantities of beans, peas, lentils and grams.

Life History. The bruchids attack not only stored grains but also peas and beans growing in the fields. The eggs are laid on the pods or grain and on hatching the larva bores through the pod or

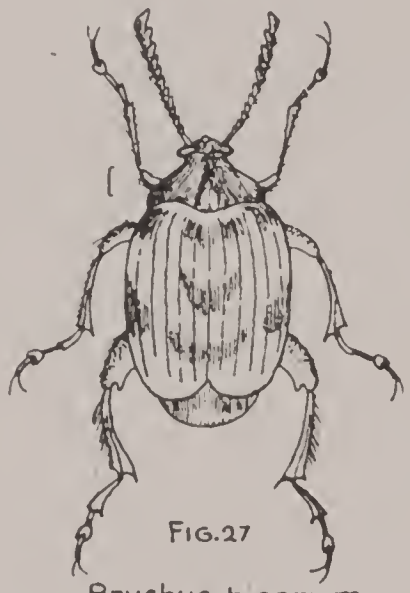


FIG. 27

Bruchus pisorum.

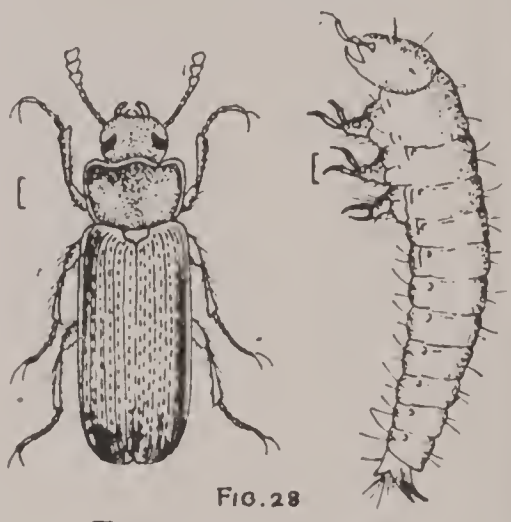


FIG. 28

Tribolium confusum.

FIG. 29

Orzaephilus surinamensis.

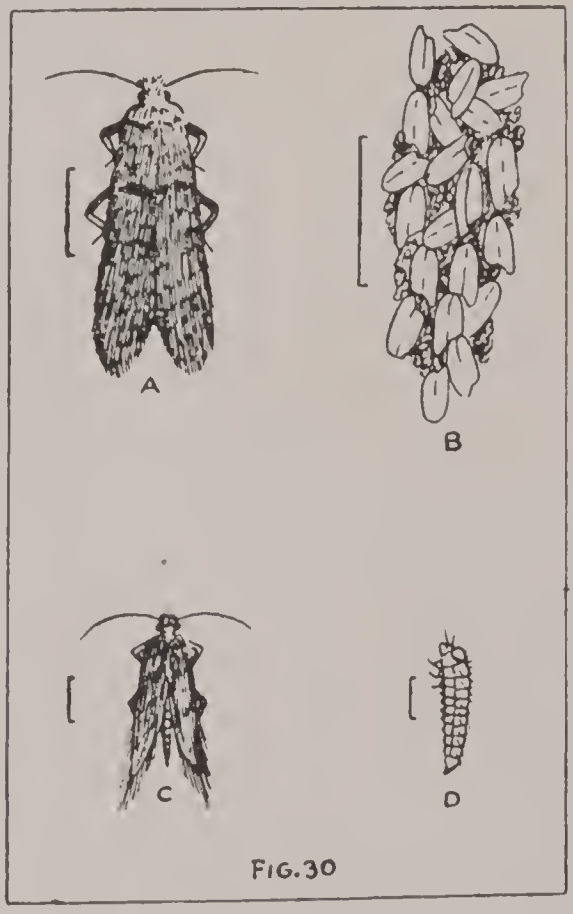


FIG. 30

directly into the grain. The full-grown larva makes an exit hole and lightly seals it, and then pupates. As many as six or seven of these insects may emerge from a single large pea seed, leaving nothing but a shell containing dusty frass.

Small Brown Beetles of Flour and Meals

Beetles of many families can breed in flours and meals. The largest of them, where the adults are about half an inch in length, belong to the genus *Tenebrio*, the larvæ of which are called " meal worms." Large quantities of " meal worms " are bred for feeding birds and other insectivorous inhabitants of zoological gardens. They are, however, not a tropical pest.

Small brown beetles of about 3–4 mm. long are common in cereal and leguminous foods in the tropics. And the commonest of these belong to the two genera *Tribolium* and *Gnathocerus*.

Tribolium. These little beetles are about 4 mm. in length. The two common species are *T. confusum* and *T. castaneum*. The reddish-brown colour, the head expanded just anterior to the eyes, and the antennal club formed by the progressive expansion of the last three to five segments indicates the genus (Fig. 28).

Life History. The eggs are laid in flour, pollards, etc. ; they are sticky so that flour adheres to them and renders them difficult to find. The incubation period is about 6 days. The larva moults six times. It may be recognized by the two sharp processes of the 9th abdominal segment (Fig. 28). The larval period lasts from 14 days onwards. The pupal period is short—4–6 days. The life phase from egg to adult is 4-9 weeks, the duration depending upon temperature, moisture and the amount of vitamin and minerals in the meal.

Tribolium multiplies very slowly or not at all in white flour because of the deficiency of vitamins, and *T. confusum* has been used to estimate roughly the amount of vitamins in flours. Fraenkel and Blewett[1] bred these insects on a synthetic diet plus the necessary vitamins in quantities of 50 γ per gm. of dry food, the temperature and humidity being kept favourable for the development of the larvæ. The following table gives their results.

[1] *Nature*, 150, 179.

TABLE LXXXI

	Period in days during which first ten pupæ were formed
Diet plus all vitamins	38–43
,, without *p*-amino-benzoic acid	36–42
,, ,, choline chloride	38–43
,, ,, thiamine	40–57
,, ,, pantothenic acid	50–61
,, ,, riboflavin, ,, ,, nicotinic acid, ,, ,, pyridoxine	all larvæ died
,, plus yeast extract	28–30

It will be seen from this that *T. confusum* needs riboflavin, nicotinic acid and pyridoxine, and possibly to a less extent panthothenic acid.

Gnathocerus. The insects of this genus are called the broad-horned flour beetles, because the males have characteristic mandibles which are nearly as long as the antennæ and protrude forwards like horns from the head, these mandibles are curved inwards and are serrated on the inner margins. The beetles are 4–5 mm. in length.

Life History. The eggs are laid singly and flour adheres to them. The larva emerges in about 7 days and grows very slowly. It moults 6 times, always moulting on the surface of the flour, which may become covered with larval skins. It takes about 6 months to become full grown, when it measures about 10 mm. It resembles the larva of *Tribolium*, but can be distinguished from it because the 9th abdominal segment carries a single up-turned pointed process. The pupal stage lasts about 6 weeks. Gnathocerus is usually found in foodstuffs infested with other pests such as the larvæ of the moths *Ephestia* and the beetles *Tribolium*; apparently it is omnivorous and includes other larvæ and pupæ in its diet.

Orzæphilus surinamensis is probably the most serious beetle pest of groceries and kitchen cupboards in the tropics. It measures 3–4 mm. in length. It has a flattened body, serrated thorax and long clubbed antennæ (Fig. 29). The larva is somewhat hairy and the life phases are passed in 3–5 weeks.

It can crawl through very small cracks to reach foodstuffs and can bore through cardboard packets. It is omnivorous and will

attack biscuits, dried fruit, sweets and many other eatables, rendering them unsightly and unpleasant to taste.

It is found in grain stores but is not a serious pest in large stores of cereals.

The Lavæ of Moths

There are many genera of small grey or fuscous moths whose larvæ may be pests of cereals or other foodstuffs. The larvæ of most of the moths can be easily recognized from the three pairs of small thoracic legs and four pairs of pseudopodia on the 3rd–6th abdominal segments. Four common species will be briefly considered.

Sitotraga cerealella. The paddy moth is straw coloured and the wing expanse varies from 11 to 15 mm. (Fig. 30, C and D).

Life History. The eggs are laid on the cereal (rice, barley, maize, sorghum, etc.) whilst ripening in the field or stored in a granary. The eggs are deposited in batches. The incubation period is from 4 to 10 days. The larva burrows into the grain. It spins a cocoon and pupates within the grain. The entire life phase is about one month. The larvæ produce a large amount of frass. The infected grains have an unpleasant smell and taste.

Corcyra cephalonica. The rice moth is a greyish moth measuring 14–22 mm. in wing expanse (Fig. 30, A and B).

Life History. The number of eggs laid by a female moth is about 150; they may be deposited on one of a large number of stored foodstuffs, such as rice or other cereal, biscuits, ground nuts, cocoa, oil seeds, currants or other dried fruit. The larval stage lasts 2–3 weeks. The larvæ are dull white in colour with a dark brown head. A dense cocoon is spun either in the food or nearby. In sacks of rice they are found attached to the inside of the sacking with frass and rice grains adhering to them. The length of the life phases is from 4 to 6 weeks.

Ephestia kühniella. A pale grey moth measuring 20–22 mm. across the expanded wings.

Life History. The female moth lays from 100 to 700 eggs on

any stored foodstuff ranging from cereals to dried fruits. The incubation period is from 4 to 12 days. The full-grown larva is larger than that of *S. cerealella*, and the legs and pseudophodia are better developed. The larvæ usually pupate away from the foodstuffs. Some quickly produce cocoons but the majority wander about the mill or store house spinning a silken thread. When present in large numbers the mass of silk produced may cover the walls, and even clog pipes and interfere with the working of machinery. The length of the life phases is from 2 to 5 months.

Plodia interpunctella. The Indian meal moth, also called the dried-fruit moth, is probably the commonest pest among the species of this genus. Although the larvæ of this moth are frequently found in flours and meals, the more serious ravages by them occur among dried fruits and sweets. They have caused great losses in the sultana, raisin and fig trades. It is a cosmopolitan species.

The moth measures from 12 to 15 mm. across the expanded wing. The fore wings have dark brown and greyish mottling and the hind wings are light grey. The female lays 200–400 eggs and the length of the life phases from egg to adult is from about 3 months to 7 or more months according to the temperature. Infested fruit becomes an objectionable and sticky mass with much frass produced by the growing larvæ and web produced during pupation.

The Control of Food Pests

This is a very difficult matter and in many cases the procedure to be adopted must be in reference to the particular foodstuff being attacked and the species of pest attacking it. But only few general principles can be considered here.

All stores should be kept as dry as possible. Grains and flours should never be stored in a damp condition. Cleanliness is of great importance and floors and walls should be frequently swept clean of refuse and pupating insects. The stored foodstuffs should be inspected at short intervals so that attacks by pests may be discovered before much damage is done. Stocks of foodstuffs should be removed from stores in the same order in which they enter them ; and old stocks should never be retained or allowed to accumulate behind new stocks.

There are two methods of destroying pests: (*a*) by fumigants,[1] (*b*) by heat.

Fumigation. It is difficult and expensive to fumigate against rats, and it is far more difficult and expensive to fumigate against most insects. Table LXXXII is from reports of Busonil on the relative toxicity of insecticides:

TABLE LXXXII

Species	Stage	Lethal dose mg. per litre					
		5 hours' exposure at 20° C.		1 hour at 25° C.			1 hour at 20° C.
		Toluene	Ethyl acetate	Ammonia	HCN	Ethyleneoxide	SO_2
Calandra granaria .	adult	90	99	8·9	22	17	10
Calandra oryzæ . .	,,	76	36	7·3	24	12	31
Ephestia kuhniella .	larva	62	50	7·7	0·4	29	16
Tribolium castaneum	adult	33	68	5·9	0·6	41	17
Tineola biselliella (cloth moth) . .	larva	55	69	—	6·5	18	24
Cimex lectularius (bug)	adult	25	25	12·0	0·14	26	6·7
Ephestia kuhniella .	pupa	—	—	—	1·6	37	—

The figures of this table can also be read as oz. per 1,000 cu. ft. because 1 oz. is approximately 28,400 mg. and 1,000 cu. ft. 28,400 l.

Sacking absorbs some fumigants such as HCN, and for this and other reasons even larger amounts than those given in Table LXXXII may be required in some grain stores.

Heat. Under many circumstances in the tropics heat is cheaper and more effective than fumigants in controlling food pests.

Calandra oryzæ ceases to breed at 31° C. (88° F.), and temperatures over 32° C. (90° F.) check the breeding of almost all common insect pests. *Rhizopertha dominica* is perhaps the most resistant and will slowly multiply at 34° C. There is, however, a factor of

[1] New effective fumigants are coming into use, among these is D.D.T. (p-p-dichlordiphenyltrichlorethane) (neocid) (cresarol). It can be used as a powder of 1–5 per cent. in a neutral dust.

humidity, and in damp granaries breeding may take place at temperatures 1 or 2 degrees higher than those stated above.

The heat in many well-founded granaries in the tropics during the warmer seasons is sufficiently high to check the breeding of pests and in some cases to destroy the adults.

The following is an example of the heat within a granary stopping breeding and killing the adults. Seven thousand bags of wheat heavily infected with *C. oryzæ* and *R. dominica* were placed in a granary at sea-level. Within two days the temperature within the sacks had risen to blood heat, and the pests streamed away from the bags. The floors became covered with dead calandra and others streamed through the crevices around the doors and were swept up into heaps in the surrounding drains, where they were seeking moisture. Rhizopertha were more resistant and the mortality among them was far less. Samples of wheat were removed from the sacks after the fifth day, and about 10 per cent. of the grains were found infested, and portions of the samples were placed under favourable conditions for the development of larvæ, but none hatched out.

The heat within granaries in the tropics only requires to be raised a few degrees to control insect pests, and this is best done by a boiler and hot-water pipes around the walls.

In some countries where the sun is seldom covered by clouds the temperature within granaries can be raised by glazing a third of the roof to form large skylights, and heat radiating on to the stores of flour or grain is soon conducted throughout the contents of the sacks. But there are disadvantages in this method; and where there are long wet seasons, during which pests flourish, it is useless.

APPENDIX I

THE EXAMINATION OF THE BLOOD IN ANÆMIAS

THE investigation of the anæmias is based upon the following determinations :

(1) The number of red cells per cmm. The instrument used is the hæmocytometer.

(2) The amount of hæmoglobin. Various instruments are in use such as Sahli's and Haldane's, the former is more suitable for work away from laboratories. The amounts are expressed in grammes of hæmoglobin per 100 ml. and not in percentages as was at one time the custom. (Different instruments have different conversion factors—Haldane 100 per cent.—13·8 gm. hæmoglobin per 100 ml. Sahli 100 per cent. varies and is marked on each instrument.)

(3) The volume of the corpuscles. Oxalated blood is centrifuged in a short graduated "barometer" tube until the height of the packed R.B.Cs. reaches constant, normally about 40 per cent. of the column of cells and plasma.

(4) The counting of the percentage of reticulocytes in a film. Normally they are less than 1 per cent.

(5) Van der Bergh reaction for bilirubin.

The following calculations are made from these determinations :

(1) *The Mean Corpuscular Hæmoglobin* (M.C.H.). This is the average hæmoglobin content of a single red cell in micromicrograms ($\gamma\gamma$). The formula is :

$$\frac{\text{Hb in gm. per 1,000 ml.}}{\text{Red cells in million per cmm.}}$$

Example : Hb found to be 12 gm. per 100 ml.
R.B.Cs. found to be 4·5 millions per cmm.

$$\therefore \text{M.G.H.} = \frac{120}{4{\cdot}5} = 26{\cdot}6\gamma\gamma$$

(2) *The Mean Corpuscular Volume* (M.C.V.). This is the average volume of a single red cell in cubic microns. The formula is :

$$\frac{\text{Volume of packed red cells per 100 ml.}}{\text{Red cells in millions per cmm.}}$$

Example : Corpuscular volume found to be 40 per cent.
R.B.Cs. found to be 4·5 million per cmm.

$$\text{M.C.V.} = \frac{400}{4{\cdot}5} = 88{\cdot}8 \text{ c}\mu.$$

(3) *The Mean Corpuscular Hæmoglobin Concentration* (M.C.H.C.). The hæmoglobin is in the R.B.Cs., and the M.C.H.C. is in other words the percentage of hæmoglobin in the R.B.Cs.

Forty-two c.c. of R.B.Cs. carrying 14·5 gm. of hæmoglobin is considered the maximum saturation.

The formula is :

$$\text{M.C.H.C.} = \frac{\text{Hb in gm. per 100 ml. blood}}{\text{Volume of packed R.B.Cs. per 100 ml. of blood}} \times 100$$

maximum saturation is :

$$\frac{14{\cdot}5}{42} \times 100 = 34{\cdot}5 \text{ per cent. Hb in R.B.C.}$$

In hypochromic anæmias the M.C.H.C. is usually low.

Example : HB=10 gm. per cent. whole blood
Corpuscular volume=35

$$\text{M.C.H.C.} = \frac{10}{35} \times 100 = 28{\cdot}5$$

The following are average figures for various populations :

	Millions per cmm.
Red blood cells :	
Men of temperate climates	5·5
Men of India (well fed)	5·4
Men of India (labourers)	5·3
Women of temperate climates	4·8
Women of India (well fed)	4·6
Women of India (labourers)	4·4
Women pregnant	4·2
Women pregnant (labourers)	4·0

	Gm. per 100 ml. blood
Hæmoglobin :	
Men of temperate climates	15·6
Men of India (well fed)	15·4
Men of India (labourers)	12·0
Women of temperate climates	13·6
Women of India (well fed)	13·0
Women of India (labourers)	11·0
Women pregnant	12·0
Women pregnant (labourers)	10·0

APPENDIX II

DETERMINATION OF VITAMIN A IN LIVERS BY THE ANTIMONY TRICHLORIDE METHOD [1]

FIVE gm. of liver are weighed in a 50-ml. beaker and minced with scissors, 10 ml. of 5 per cent. solution of KOH is added and the material is transferred to a 50-ml. conical flask. The mixture is digested in an oven at 100° C. until there is complete solution. It is poured into a 100-ml. graduated and stoppered funnel and 5 ml. of ethyl alcohol is added and well shaken, 50 ml. of ether is added and the shaking repeated. The layers are allowed to settle out and the aqueous layer is run off and discarded ; 5 ml. of water is added and vigorously shaken with the other layer ; the aqueous layer settles and is discarded ; this washing to remove the KOH is completed by gentle agitation with 50 ml. of water (vigorous shaking produces an emulsion which will not readily settle into layers). The ether fraction is passed into a small flask containing anhydrous sodium sulphate and allowed to stand for a few minutes : this absorbs the water ; the ether is filtered through a little more anhydrous sodium sulphate in a dried sintered glass funnel leading into a 100-ml. wide-neck squat flask. The content of the flask is evaporated on a water bath, and to prevent condensation of moisture the flask is fitted with a cork through which two tubes pass—one leads to two wash-bottles, the first contains sulphuric acid and the second caustic potash, the other leads to a suction pump, thus only dried air enters the flask. The residue after evaporation should be a clear and transparent oil ; it is dissolved in 2 ml. of this solution into a 1 ml. Lovibund cell and the volume is made up to 0·5 ml. Two ml. of antimony trichloride in dry chloroform (Carr-Price reagent) is added from a B.D.H. automatic pipette ; as the blue colour appears it is quickly matched in a Lovibund tintometer with blue and yellow glasses. Supposing the contents of the cell are matched by 5 Lovibund blue units (and the necessary yellow glasses). The calculation is made as follows :

$$\frac{5 \text{ blue units} \times 2{\cdot}5 \text{ (the volume of reaction mixture)} \times 2 \text{ (amount of chloroform)}}{\text{Amount giving } 5 \text{ blue units} \times 5 \text{ (grams of liver)}}$$

Supposing 0·2 ml. gave 5 blue units, then :

$$\frac{5 \times 2{\cdot}5 \times 2}{0{\cdot}2 \times 5} = 25 \text{ blue units per gm. of liver}$$

[1] Adopted from A. W. Davies (1933, *Biochem. Jour.*, XXVII, p. 1770).

When a large number of blue units is present it is necessary to dissolve the evaporated residue in a greater quantity of chloroform, such as 5 or 10 ml.

The value in International Units can be determined in each case by checking against an oil of known value.

A factor which has been used to convert blue units into International Units is 4·2 (Bomskov, 1935).

APPENDIX III

Hess Capillary Resistance Test

Fix the armlet of a sphygmomanometer above the elbow as in taking blood pressure. Note any purpuric spots which may be present on the forearm and mark them with a grease pencil. Determine the systolic and diastolic pressure and maintain the pressure within the armlet at a point midway between systolic and diastolic for five minutes. Release the pressure and examine the forearm in a good light with a hand lens. Capillary resistance below normal is shown by the appearance of a number of fresh purpuric spots.

The process may be repeated on the other arm.

Capillary Fragility Test with Suction Pump

A small glass cup fixed to a suction pump having a manometer and vacuum release screw (Fig. 31) is applied to the skin and the degree of

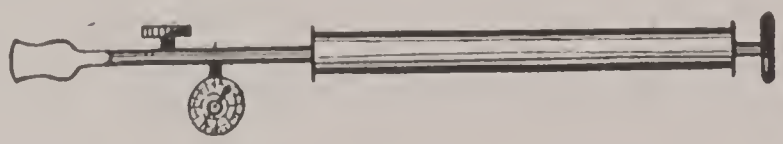


FIG. 31

Suction Pump for testing capillary fragility

capillary fragility determined by the amount of negative pressure which will produce ecchymosis. When carrying out the test the same body area should always be used, the size of the cup standardized, and the effect of the administration of ascorbic acid or citrin should be determined for those who show capillary fragility.

APPENDIX IV

DETERMINATION OF VITAMIN C IN THE URINE

All the urine passed during 24–36 hours should be examined, as the excretion of vitamin C does not take place at a uniform rate but is greatest about one hour after meals. The urine should be examined immediately after it has been passed ; when this is impossible it may be preserved up to but not longer than 10 hours by the addition of 10 per cent. by volume of glacial acetic acid, and keeping the acidified urine in a cold place.

The reagent used is a freshly made solution of the dye 2·6 dichlorophenolindophenol, which is reduced by ascorbic acid to a colourless compound.

To 10 ml. of urine is added 10 ml. of water and 1 ml. of glacial acetic acid. A solution containing 0·004 gm. of dichlorophenolindophenol (2 tablets of 0·002 gm.) in 100 ml. of water is placed in a burette. The diluted urine is titrated until the purple colour of the dye ceases to disappear and remains pink for a few moments. The number of cubic millimetres of the solution run from the burette multiplied by 0·24 gives the quantity of vitamin C in mg. per 100 ml. of urine. The titration must be carried out rapidly because there may be other substances in the urine which reduce the dye but more slowly than ascorbic acid.

The amount of ascorbic acid in the urine of well-fed persons is about 1·55 mg. per 100 c.c.

This method can also be used to determine the amount of ascorbic acid in the juices of foodstuffs. The " indophenol " solution does not keep and must be standardized daily.

APPENDIX V

DENTITION TABLE

Deciduous (milk) teeth

Central incisors, lower	6–8th month
,, ,, upper	7–9th ,,
Lateral incisors, upper	9–10th ,,
,, ,, lower	10–13th ,,
First molars	12–14th ,,
Canines	17–20th ,,
Second molars	2nd to 3rd year

Full dentition 10 teeth in each jaw.

Permanent teeth

First molars	6th year
Central incisors	6–7th ,,
Lateral incisors	8th ,,
Lower canines	10th ,,
First premolar	10th ,,
Upper canines	11th ,,
Second premolar	11th ,,
Second molars	14th ,,

Full dentition 16 teeth in each jaw.

APPENDIX VI

DETERMINATION OF PROTHROMBIN IN BLOOD (PROTHROMBIN TIME)

Apparatus Required

(1) Serum syringe for obtaining blood from the patient.
(2) Centrifuge with dry tubes.
(3) A rack with six small dry tubes.
(4) A water bath maintained at 37° C.
(5) Capillary pipettes and tests.
(6) Stop watch.

Solutions Required

(1) Sodium oxalate solution—1·34 gm. pure anhydrous sodium oxalate in 100 ml. distilled water.
(2) Calcium chloride—1·11 gm. $CaCl_2$ in 100 ml. distilled water. This must be checked by titration with silver nitrate solution.

$$CaCl_2 + 2AgNO_3 = Ca(NO_3)_2 + 2AgCl$$
$$111 \quad 2(170)$$

(3) Thromboplastin solution. Either of the following solutions may be used :

(*a*) Cut up a rabbit's brain and press the pieces through fine wire gauze to remove the blood vessels. Stir the broken-up brain into acetone, pour off the acetone, and repeat this several times to produce a dry granular powder. This keeps well in cold storage.

To prepare the solution, stir 0·3 gm. of the dry powdered brain into 5 ml. of normal saline containing 0·1 ml. of sodium oxalate solution, place the tube in a beaker of water at 45° C. for 10 minutes, centrifuge at a low speed for 5 minutes. Pipette off the milky supernatant fluid, this is the thromboplastin solution, and under a film of toluene will keep for about 3 weeks in an ice chest.

(*b*) A 1 in 20,000 solution of Russell's viper venom. The dried venom keeps indefinitely in cold storage. And under toluene the solution keeps for about one month.

TECHNIQUE. *Quick's Method Slightly Modified.* 4·5 ml. of blood drawn from the patient into a dry syringe is passed into a centrifuge tube containing 0·5 ml. of sodium oxalate solution. Centrifuge to separate the plasma, which is pipetted off into a dry sterilized tube. 0·2 ml. of plasma is placed into each of three tubes marked 1, 2 and 3. Place in each of three dry test-tubes 0·2 ml. of thromboplastin solution and 0·2 ml. of calcium chloride solution. Place one tube containing plasma and one tube containing thromboplastin and calcium solutions in the water bath at 37° C. and when warm mix the contents, start the stop-watch, shake the tube and watch for clot to appear, and note the time of appearance. Repeat with the other two tubes. The prothrombin time is the mean of the three times. Normal is from 15 to 25 seconds.

APPENDIX VII

ATWATER'S BOMB CALORIMETER (Fig. 32)

This consists of an outer chamber of insulating material (A) (Fig. 32) within which is supported a vessel (B) to hold water. The innermost chamber is a heavy steel bomb (C) with a gold-plated copper lining and having a lid which can be hermetically sealed by means of a screw collar (D); a small crucible (E) with an electric fuse attached is suspended within

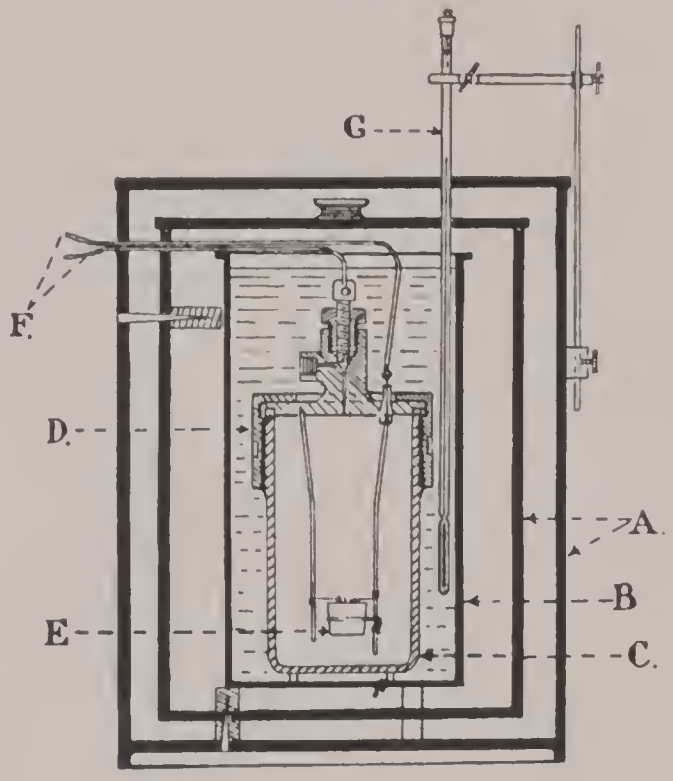


Fig. 32

the bomb; two electric terminals (F) are attached for firing the fuse. There is a tube in the lid of the bomb through which oxygen can be passed, and held under pressure. A thermometer (G) registering to one-thousandth of a degree is suspended in vessel (B).

When the caloric value of a sample of foodstuff is to be determined, the bomb is removed from the apparatus and a weighed quantity of a dried sample is placed in the crucible, the lid is screwed on and oxygen to a pressure of at least 20 atmospheres is passed in and the tube sealed. The bomb is immersed in a weighed quantity of water and the tem-

perature is noted. The sample is ignited through the electric fuse and the oxygen under pressure causes complete combustion. The heat liberated raises the temperature of the water, and this is read to a thousandth of a degree. There are many details to be observed and corrections for various heat effects to be made when using this apparatus.

APPENDIX VIII

A LIQUID EXTRACT OF YEAST FOR MEDICINAL PURPOSES

One lb. of brewer's yeast is thoroughly stirred into 500 c.c. of rectified spirit. After six hours the spirit is separated by centrifuging for half an hour. The deposited yeast is emulsified with 250 c.c. of fresh spirit and left overnight ; it is again centrifuged and the two lots of spirit extracts mixed. The deposit is emulsified with 500 c.c. of water, allowed to stand for a few hours and centrifuged, the supernatant fluid is removed, and the deposit is again emulsified with water (250 c.c.), and centrifuged, and the two water extracts mixed. The alcoholic extract is evaporated at low pressure at 70–75° C. to a quarter of its volume. The residue is added to the water extract. Glycerine, benzoic acid and ol : anisi are added as preservatives in the following proportions :

Extracts of yeast	800 c.c.
Glycerine	40 c.c.
Benzoic acid	2 gm.
Ol : anisi	7 c.c.

The dose ranges from one teaspoonful three times a day for very young children.

This preparation keeps for several weeks at room temperature.

APPENDIX IX

INSTRUCTIONS FOR DIETARY INQUIRERS

THE following instructions were issued to school inspectors carrying out a preliminary inquiry among the school children of Ceylon :

When conducting an inquiry in a school each child should be questioned separately, and his or her replies should not be overheard by other children ; this will avoid the results of suggestion.

It is not necessary to question more than 100 children in each school ; and only those between the ages of 8 and 12 should be questioned.

Great care should be taken to obtain all details.

The following points should be noted when filling in the Diet Inquiry Form.

TYPE OF SCHOOL. Vernacular or English, paying or non-paying.

Morning Meal :

(1) Time of day when taken.

(2) Kind of food.

(*a*) If hoppers state whether white hoppers, string hoppers, jaggery hoppers, pittu or roti. How many ? Were these eaten alone or with jaggery, scraped coconut or sambol ? What kind of sambol ?

(*b*) If rice, state whether (1) hand pounded ; (2) parboiled ; (3) milled, muttusamba, milchard, etc. If maize, state preparation.

(*c*) If millet, in which form, pittu, roti or thalapa.

(*d*) If fruit, give the name : jak, palmyra, bread fruit, etc. How was it eaten, *e.g.* alone or with sambol or scraped coconut ? Was it raw or cooked ?

(*e*) If yam, state the kind.

(*f*) If gruel alone—how was it prepared ?

(*g*) Was bread eaten—how much ?

(3) Was tea taken ? With milk or without—with sugar or jaggery or without ? Was toddy taken, sweet or fermented ?

Midday Meal :

(1) Time of day when taken.

(2) Kind of food.

(*a*) Rice, state kind as above.

(*b*) Any other foods as above.

(*c*) Vegetables. The vernacular name of the kind taken should be stated. In the case of vegetables in which more than one part of the vegetable is edible (for instance the leaves and roots of radish are both edible), the part taken should be stated.

(*d*) Dhals, grams and peas—state kind, whether red or yellow dhal, black or green gram, etc.

(*e*) Fish—state kind such as sprats or variety of larger fish. State whether fresh, salted or dried—shell fish—prawns, crabs, etc.

(*f*) Meat—state kind—beef, goat, etc.

(*g*) Coconut—state whether taken grated, or milk as prepared for curry.

(*h*) Oils—state if any oil, such as coconut or gingelly, was used for cooking.

(*i*) Ghee—was ghee used in cooking the food ?

(*j*) Fruits—state if possible the kind of banana or plantain or other fruits.

(*k*) Was sambol taken ? What kind ? Any kind of gravy or such.

Evening Meal :

Points as for midday and morning meals. Was butter or jam taken at any meal ?

Extras :

Mention any extras—rice cakes, peas, fruit, toddy, etc., taken between meals during the last twenty-four hours.

Betel :

Does the child ever chew betel ?

DIET INQUIRY FORM

To be filled in for each child

TYPE OF SCHOOL : DATE :
NAME OF SCHOOL : PROVINCE :
AGE : RACE : PARENT'S OCCUPATION :

Morning meal of to-day. Time when taken :	Midday meal of yesterday. Time :	Evening meal of yesterday. Time :

Extras during last 24 hours :

APPENDIX X

AVERAGE HEIGHTS AND WEIGHTS OF FAIRLY WELL-GROWN BOYS AND GIRLS

	Boys				**Girls**			
	Height		*Weight*		*Height*		*Weight*	
Age	*cm.*	*in.*	*kg.*	*lb.*	*cm.*	*in.*	*kg.*	*lb.*
1 day	50	20	3·2	7	50	20	3·2	7
2 weeks	51	20½	3·7	8	51	20½	3·7	8
1 month	53	21	4·4	9½	53	21	4·4	9½
3 months	57	23	5·6	12¼	57	23	5·6	12½
5 ,,	60	24	6·4	14	60	24	6·4	14
8 ,,	65	26	7·5	16½	64	25½	7·4	16¼
12 ,,	70	28	9·0	20	70	28	9·0	20
2 years	80	32	11·5	25½	80	32	11·5	25½
3 ,,	88	35	13·5	30	88	35	13·5	30
4 ,,	96	38½	15·5	34	95	38	15·3	33½
5 ,,	103	41	17·5	38½	102	41	17·0	37½
6 ,,	109	43½	19·0	42	108	43	18·5	41
7 ,,	117	46	21·3	47	115	45	20·4	45
8 ,,	122	48	22:7	50	120	47	22·2	49
9 ,,	127	50	25·0	55	125	49	24·0	53
10 ,,	132	52	27·0	60	131	51½	27·0	59½
11 ,,	137	54	30·0	66	136	53½	29·0	64
12 ,,	142	56	32·6	72	141	55½	32·6	72
13 ,,	146	57½	35·4	78	147	58	36·7	81
14 ,,	150	59	40·0	88	153	60	41·7	92
15 ,,	158	62	45·4	100	155	61	44·4	98

APPENDIX XI

THE A.C.H. INDEX OF NUTRITION [1]

THE A.C.H. (A=arm, C=chest, H=hip) index is the result of the work of Franzen and Palmer on behalf of the American Child Health Association. The methods and principles underlying its construction are roughly as follows :

Large numbers of children (over 10,000) were examined by competent pædiaticians and their state of nutrition assessed by clinical examination. From the same children a very complete set of measurements was taken, including shoulder breadth, hip width, chest width and depth, height, weight, arm and calf girth, size of deltoid and thickness of the subcutaneous tissue of different areas of the arms and legs. By elaborate statistical treatment, the correlation between the presence of malnutrition as determined by clinical examination and the various measurements was worked out. Ultimately it was found that a certain relationship between arm, chest and hip measurements was associated with a diagnosis of malnutrition, other measurements being discarded as unnecessary for practical purposes. In practice, the observer measures the circumference of the arm at the highest point of the biceps with the arm flexed and extended ; the anterior-posterior diameter of the chest during inspiration and expiration ; and the width of the hips from trochanter to trochanter. He then consults a chart which gives the *minimum* difference between arm girth and chest depth for a certain width of hip. If the difference in the child examined is less than the figure in the chart that child is selected as suffering from malnutrition. According to the principles on which it is based the index picks out the children to whom an experienced physician would affix the label " malnutrition." Such children have " small amount of musculature and fatty tissue relative to body build." Statistical analysis showed that American physicians pay more attention to the state of muscular and adipose tissue than to any other sign or symptom.

To make these points more comprehensible to those not familiar with the index, the chart used in " selection " is reproduced in full. As

[1] Quoted from W. R. Aykroyd and K. Rajagopal (*Ind. J. Med. Res.*, 1936, XXIV, 422).

previously stated, two measurements of arm girth and chest depth, respectively, are taken. These are added together before subtraction.

Supposing a boy's hip width is between 23·0 cm. and 23·4 cm. If the difference between the arm girth and chest depth is less than 3·3 cm. he is " selected."

The A.C.H. Chart

Width of hips (cm.)	BOYS Minimum difference between arm girth and chest depth (cm.)	GIRLS Minimum difference between arm girth and chest depth (cm.)
Below 20·0	0·0	0·5
20·0–20·4	0·0	1·0
20·5–20·9	0·4	1·6
21·0–21·4	1·0	2·1
21·5–21·9	1·6	2·6
22·0–22·4	2·2	3·0
22·5–22·9	2·7	3·4
23·0–23·4	3·3	3·8
23·5–23·9	3·8	4·2
24·0–24·4	4·2	4·5
24·5–24·9	4·7	4·5
25·0–25·4	5·1	5·1
25·5–25·9	5·6	5·4
26·0–26·4	6·0	5·6
26·5–26·9	6·3	5·8
27·0–27·4	6·7	6·0
27·5–27·9	7·0	6·1
28·0–28·4	7·3	6·2
28·5–28·9	7·6	6·3
29·0 and over	7·9	6·4

APPENDIX XII

NUTRITIONAL SECTION OF A FOODCRAFT EXHIBITION

This exhibition was held in Ceylon in 1943. One of the aims of the exhibition was to popularize various substitutes which had become necessary under war-time rationing. But most of the exhibits and much of the advice given is applicable to peace-time conditions.

The Nutritional Section of the Exhibition is described here as it may be of use to those doing similar nutritional propaganda work in other countries.

The temporary hall was 100 ft. by 30 ft. There were six large glass cases (6 ft. by 3 ft.) and four somewhat smaller cases. The only actual foodstuffs exhibited were those which will keep, such as dried grains ; in all other cases the exhibits were in the form of models.[1]

[1] Models of fruits, vegetables, heart, kidneys, fish, etc., can be easily and quickly made by the following method :

A material for making excellent negative moulds was prepared by Mr. T. D. de Alwis of Ceylon, and has been called " Alwisite," the following is the method of preparation :

> Twenty gm. of agar is placed in 200 ml. of water in a saucepan, boiled over a naked flame. It must be continually and thoroughly stirred. When the agar has melted and the mass is of even consistency, 8 gm. of fine plaster of paris, or other insoluble powder, is slowly added to the molten boiling mass. Finally 2 gm. of cotton wool is added flake by flake and thoroughly stirred in. This moulding material sets at 45° C. and melts at 95° C.

Moulds can be made of small objects, such as fruits, by pouring the melted material over them in several layers, and then cutting the mould into two equal halves. A " wax " suitable for making the models can be prepared by stirring fine plaster of paris or other insoluble powder into heated paraffin wax. The degree of hardness depends partly on the melting-point of the paraffin wax, but to a greater extent on the amount of powder added to it.

The modelling wax should be appropriately coloured for each exhibit by stirring a dry pigment into the melted wax ; the colour being the prevailing ground colour of the exhibit.

The wax is poured into each half of the mould, and when it has set is removed and the two halves stuck together by heating the edges.

When making moulds of large objects, the moulding material is put on in layers and on to each layer is laid cotton or wire gauze cloth to strengthen the mould. Similarly, large models are made strong and light by a rough pattern of the object in wire gauze supported within the mould, the wax being poured between the mould and the rough pattern.

The moulds for some models, such as leaves or flat fish, can be conveniently pre-

On stands along the walls were ranged numerous food plants in large wooden pots ; and among these were flowering millets, bandakka (ladies' fingers), brinjal (egg plant), chillies, pineapple, sweet potato, yams, and many leaves such as amaranthus, centella, sesbania, etc. These had appropriate legends.

Case 1, at the right hand of the entrance, contained the constituents of foodstuffs in bottles or small tubes in more or less the proportions in which they occur in foodstuffs.

Poster Over Case I

THE CONSTITUENTS OF FOODSTUFFS

Bulk of diet	*Minerals*	*Vitamins*
Protein	Salt (sodium chloride)	Vitimin A (soluble).
Carbohydrates	Lime (calcium salts)	Vitamin D (in fats).
Fats	Iron	Vitamin B complex,
	Phosphorus	Thiamine B_1,
		Riboflavin B_2,
		Nicotinic acid.
		Vitamin C (anti-scurvy).

Case II contained many samples of grain foods.

Poster Over Case II

THE GRAIN FOODS

Almost all dry grain foods are either *cereals or pulses*. All of them have almost the same energy value (100 calories per oz.).

The *pulses* are twice as rich in protein as the cereals and have been called the " poor man's meat." They are also rich in certain vitamins. They are less digestible than the cereals.

pared by placing these objects on a piece of glass and pouring the moulding material over them.

The natural appearance of the models will depend upon the artistry of the modeller in his final touching up and painting.

Enlarged models of insects, pests and other objects must be modelled freehand. They can be robustly constructed on a framework of wire gauze to which wires, which will become the legs and other appendages, are soldered. But someone with a knowledge of entomology must draw up the plans to scale and watch the construction.

The Cereals

Rice, Wheat, Oats, Maize, Millets, etc.

Oats and Wheat are the most nutritious.

The vitamins are in the outer coats of the rice grain, hence, rice should be *lightly milled* so that only the outer bran is removed. Parboiling distributes the vitamins throughout the grain.

Lightly milled parboiled rice is *the best.*
Lightly milled raw rice is *good.*
Highly milled raw rice is *bad.*

The bran of wheat is indigestible and may be removed. But the rest of the grain (95 per cent.) is far better than white flour.

Pulses

(Peas and Beans)

The dhals, green gram black gram and rough gram are the best. The dhals are most digestible. The cow pea and the lima beans are fairly good pulses but should not be taken frequently.

The ground nut is a pulse, and is a good one.

Case III. Models of Vegetable Fruits with their food values.

Poster Over Case III

Vegetable Fruits

These are necessary to supply the needed vitamins.

The Gourds and Pumpkins. The best of these are the red pumpkins, snake, bitter and ridge gourds. The cucumber is of less value. The water and ash pumpkins have little or no dietary values though they are pleasant to eat with curries.

Bread Fruit and Jak Fruit. These have much the same substantive values as potatoes and other roots.

Miscellaneous Vegetables. Plantain, tomatoes, brinjals, bandakka, drumsticks, string beans and green chillies are all good vegetables.

Drumsticks are particularly valuable in the Dry Zone.

Case IV. Models of Fruits with the Food Values.

Poster Over Case IV

FRUITS

Many fruits are health giving because they are rich in the anti-scurvy vitamin C, and can correct acidity. They may be placed in the following groups :

(1) *Juicy Fruits of High Value.* Rich in vitamin C. Also rich in citric, malic and other acids which become alkalis in the body, and thus we have the paradox of acids neutralizing acids.

(2) *Yellow Fruits of High Value.* These are rich in vitamin A value and fairly rich in vitamin C.

(3) *Fruits of Substantive Food Value.* The banana is the chief example of these.

(4) *Fruits of Small Value.* There are many pithy or spongy tropical fruits which have only small values.

(5) *Fruits of Medicinal Value.* The astringent Bael Fruit is an example of these.

Case V. Various roots and their values. (Yams, Manioc, Sweet Potatoes, Tania, etc.)

Case VI. Foodstuffs of Animal Origin.

This case contained models of meat, fish, dried fish, shell fish, eggs, kidneys, liver and a bottle of milk.

Posters Over Case VI

FOODSTUFFS OF ANIMAL ORIGIN

Vegetarianism may be satisfactory for those who have reached middle age, but foodstuffs of animal origin are essential for good growth and health of children, and for the activities of young men and women.

A GREATER PRODUCTION OF FISH
IS A NECESSITY

Shell fish (prawns, etc.) have fair values, but are unsuitable for some people.

INFANTS MUST BE WEANED
ON COW'S MILK OR
GOAT'S MILK

Sprats and Other Small Fish

Apart from milk these are the best sources of lime for the growing bones of children, and therefore should be in their diets frequently.

Eggs

"Treasure houses wherein lie
Locked by angel's alchemy
Milk and hair and blood and bone."

The poet is nearly right, but not quite. Eggs are highly nutritious but do not contain all human requirements for growth or maintenance. The body of the developing chick can produce two vitamins which the human body cannot; also the chick obtains much lime for its bone from the shell.

LIVER IS THE RICHEST FOODSTUFF FOR VITAMINS IN GENERAL

KIDNEYS ARE ALSO A GOOD SOURCE OF VITAMINS

Case VII. Contained models and samples of three diets.

(A) was a typical unsatisfactory diet of the labouring classes.

(B) and (C) were of satisfactory diets in compliance with the posters over the case.

Posters Over Case VII

WHAT IS WRONG WITH CEYLON DIETS ???

(1) *Too Much Rice.* Some of the rice should be replaced by other cereals, such as Wheat, Millets and Maize.

(2) *Not Enough Pulses.* Dhals, Grams or Beans should be taken daily.

(3) *Not Enough Roots.* Sweet Potatoes or Yams should be taken daily.

(4) *Not Enough Green Vegetables.* Salads (Mellums) daily are essential.

(5) *Not Enough Fruits.*

(6) *Too Much Condiments.* Cut out excessive currystuffs.

CHILDREN'S DIETS

(1) Not Enough Milk.

(2) Not Enough Small Fish (Sprats and Whitebait).

How to Improve Ceylon Diets

Before Japan entered the war many people took too much rice ; some of the rice should be replaced by other cereals such as wheat, maize and millets.

Wheat is a very nutritious cereal.

More pulses, roots, vegetables and fruits should be taken.

(A) Series of models represent Ceylon Diets.

(B) and (C) Series of models show how to improve Ceylon Diets.

The amount shown are for a man on light work.

More will be required for a man on hard work.

Cases VIII and IX showed models and samples of substitutes for war-time conditions.

Case X contained models showing the life histories of common pests of grains, etc.

Posters Over Case X

Pests of Grains and Flours

Weevils of Rice, Wheat, etc. (*Calandra oryzæ*).

Life History

(1) The weevil bores a hole in a grain and lays an egg in it.

(2) The egg hatches into a maggot which as it grows destroys the grain (Model 1).

(3) The maggot passes through various stages and becomes an adult, which escapes from the grain (Model 2 the empty grain).

(4) The adult (Model 3).

Each female lays eggs in about 200 grains.

The Little Flour Beetle
(Tribolium confusum)

(1) The beetle lays eggs in flour or grain.

(2) The eggs hatch into maggots which wander about the flour.

(3) These maggots undergo changes and become adult beetles.

(4) Each female lays many eggs.

Model 7 is the maggot greatly enlarged.

Model 8 is the beetle greatly enlarged.

Weevils of Peas and Beans
(*Bruchus*)

These weevils lay several eggs on each grain, maggots hatch out and bore into the grains and gradually destroy it.

Model 4. Weevil maggot in pea.
Model 5. Dried pea destroyed by Weevil.
Model 6. The pea Weevil.
The models show the peas and insects greatly enlarged.

Moths of Flours and Grains
(*Ephestia*)

These little moths lay eggs on the outside of bags of flour or grain.
A little caterpillar hatches out and enters the flour and grows, in time it spins a cocoon and a moth hatches out.

Model 9. The Caterpillar greatly enlarged.
Model 10. The Moth greatly enlarged.

Control of the Pests

The walls and floors of all grain stores should be frequently swept clean. The walls should be lime-washed. The grain should be thoroughly dried in the sun, and stored in bins with well-fitting lids ; or in boxes in which all cracks and joints have been well sealed with paste or clay. Dry grains, placed in heaps, and covered with clean dry sand keep well.

ALL PESTS CAN BE DESTROYED BY FUMIGATION

There were cages of rats. Some had been fed on ample diets and were well grown, and others had been fed on deficient diets and were unhealthy and stunted.

Among other Posters were :

> " Education is the right of Every Child, and a new doctrine is gaining ground that proper food for good growth and health is also his or her right."

VARIETY IS THE KEY NOTE OF GOOD DIETRY

DEFICIENT FOOD

The diets of the Labouring Classes must be improved.

" Ill fares the land to hasting ills a prey,
Where wealth accumulates and men decay."

Prior to the war great wealth was accumulating in many countries, and yet there was much unemployment and its consequent malnutrition.

TOO MUCH FOOD

Diabetes

" 'Tis only tramps in rags
And gluttons old in sin
Who stuff themselves like carpet bags
When taking victuals in."

All cases of diabetes are not due to gluttony, but *some are*, especially among those of sedentary occupation.

Over engorgement with rice heavily laced with currystuffs leads to diabetes.

(This would not apply to all countries.)

TRANSLIGHTS

There were rows of large coloured photographs translighted. These were labelled " Some Signs of Malnutrition " and showed common conditions such as :

Sore tongue, Angular stomatitis, Phrynoderma, Bitot's Spots, Nutritional Œdema and emaciation with rough skin.

There were also other coloured translights of edible leaves.

APPENDIX XIII

TESTS FOR HCN IN FOODSTUFFS

A Qualitative Test. A simple test for the presence of HCN in foodstuffs is as follows :

Slips of filter paper are soaked in the following reagents :

Sodium carbonate . .	5 gm.
Picric acid . . .	0·5 gm.
Water	100 c.c.

The slips of paper are allowed to dry, and will keep for several weeks.

The foodstuff is pounded into a pulp, and moistened if necessary, and a quantity is placed in a test-tube so as to occupy about 2 in. of the lower end. A slip of the yellow picric acid paper is attached to a cork and inserted into the test-tube above the pounded foodstuff. The slip of paper should be slightly moist. Any HCN liberated from the glucosides of the foodstuff will slowly turn the yellow paper a brown colour. When there is a large amount of HCN given off the brown colour appears in a few minutes, but when small amounts of HCN are present the colour may not appear for several hours.

A Quantitative Test. The foodstuff, such as manioc root, is weighed and quickly pounded to a pulp and placed in a little water in a large distilling flask. A glass tube leads into the pulp and water. Another tube from the flask is connected in series with three large test-tubes, the first two contain about 10 ml. of 5 per cent. KOH, and glass tubes lead below this potash. The last test-tube is connected to a filter pump so that air can be rapidly drawn from the flask to bubble through the potash. The large flask is placed on a water bath heated to 45° C. The enzyme of the foodstuff sets free the HCN which is carried by the aeration and absorbed by the potash. To exhaust the HCN given off, air should be drawn through the pulp and water and into the potash for 12 hours. The amount of HCN absorbed by the potash is determined by titration with M/100 silver nitrate, a few drops of 5 per cent. KI being used as indicator. When all the cyanide has formed the soluble double salt AgCN.KCN, a cloud of precipitate of AgI appears. The estimation is 1 ml. of M/100 silver nitrate+0·0005404 of HCN. For other details, see L. R. Bishop (1927), *Biochem. J.*, XXI, 1,163.

APPENDIX XIV

DETERMINATION OF FLUORINE IN WATER

Sanchis Method. This method depends upon the bleaching qualities of fluorides on the purple lake formed by a mixture of zirconium nitrate and Alizarin—S. The sensitivity of the reaction is increased by free acids. The bleaching power of the water being examined is compared colorimetrically with that of standards.

The stock solution of the indicator is prepared by mixing a 0·87 per cent. solution of zirconium nitrate with an equal volume of a 0·17 per cent. solution of Alizarin—S. This solution is diluted five times before use.

Each of 100 ml. of the sample (filtered if not clear) and 100 ml. of standards containing 0, 0·25, 0·5, 0·75, 1, 1·5, 2, 2·5 and 3 parts per million of fluorine in the form of added fluoride is mixed with 2 ml. of 3N.HCl, 2 ml. of $3N.H_2SO_4$ and 2 ml. of the above indicator solution. These solutions are quickly boiled and allowed to stand for 4 hours in a dark cupboard or box, and then the colours are compared. The flasks used must be uniform in size and thickness of glass.

APPENDIX XV

THE WEIGHT OF THE KERNEL IN COCONUTS OF VARIOUS SIZES

The following are details of fresh clean husked coconuts as bought in the market :

Weight of nut		*Circumference of nut*		*Weight of kernel*	
oz.	*gm.*	*in.*	*cm.*	*oz.*	*gm.*
24	680	$12\frac{1}{2}$	32	$10\frac{1}{3}$	292
25	709	$12\frac{1}{2}$	32	$10\frac{1}{4}$	287
26	737	$13\frac{1}{2}$	34·5	$10\frac{1}{2}$	297
26	737	$13\frac{3}{4}$	35	$11\frac{1}{2}$	326
30	850	14	35·5	$12\frac{1}{3}$	348
30	850	14	35·5	13	369
31	879	14	35·5	13	369
36	1,020	15	38	16	454
36	1,020	16	40·5	17	482
45	1,276	16	40·5	$18\frac{1}{4}$	516
47	1,332	16	40·5	$17\frac{1}{2}$	496
48	1,360	17	43	19	538

It will be seen from the above that the value of coconuts varies greatly. It may be accepted for practical purposes that an average coconut of 30 oz. contains 12 oz. of edible kernel.

APPENDIX XVI

EDIBLE PERCENTAGE OF FOODSTUFFS AS BOUGHT IN THE MARRET

Percentage edible :

90 per cent. or more	Brinjals (egg plant), new potatoes, some yams.
80–90 per cent.	Potatoes, sweet potatoes, papaw and most yams.
70–80 ,,	Ash plantains, bananas, tree tomatoes.
60–70 ,,	Bael fruit, bread fruit, drumsticks, gourds, pumpkins, jak fruit, manioc root, leaves, pea nuts in shell.
35–50 ,,	Oranges (juice 35 per cent.), limes (juice 45 per cent.), mangos, passion fruit.
Less than 35 per cent.	Some fruits such as mangosteens.

The amount of waste in meat and fish is very variable. Hospital contracts usually contain a clause that there shall be not more than 10 per cent. of bone. In the case of fish that they shall be gutted and without heads, gills or tails.

APPENDIX XVII

THE WEIGHT OF MEASURED GRAIN

GRAINS are frequently measured in preference to weighing them. The measures used are : 1 quart (often called a *Measure*)=2 pints, 8 quarts =1 peck, and 4 pecks (32 quarts)=1 bushel. The measure is filled with the grain and levelled by passing a rod across it to remove any grain heaped up above the level of the walls of the measure. This is called a " Cut Measure," to distinguish it from the indefinite heaped-up measure.

The following are roughly the weights in oz. of quarts (cut measures) of various grains, etc. :

	oz. per quart
Beans (horse), *Canavalia, ensiformis*	24
Beans (flat), *Dolichos lablab*	29
Beans (lima), *Ph. lunatus*	29
Coriander in husk	14
Dhal	31
Gram (small)	32
Maize	$29\frac{1}{2}$
Millet (Setacia italica)	31
Mustard seed	25
Rice	32
Wheat	31
(Salt	32)

A measure of grain in the husk is far lighter than a measure of husked grain. For instance, a quart of paddy weighs 24 oz. and the husked and pounded or milled rice from it weighs only about 16 oz. Therefore about two measures of paddy are about equivalent to one measure of rice.

A measure of flour is much lighter than a measure of grain, but flours cannot be satisfactorily measured.

APPENDIX XVIII

WEIGHTS AND MEASURES

Metric System :

Measure of Length

1 Kilometre (km.)	1,000·0 m.
1 Metre (m.)	1·0 m.
1 Centimetre (cm.)	0·01 m.
1 Millimetre (mm.)	0·001 m.
1 Micron (μ)	0·001 mm.
1 Millimicron ($\mu\mu$)	0·001 μ

Measure of Weight

1 Kilogram (kg.)	1,000·0 gm.
1 Gramme (gm.)	1·0 gm.
1 Centigram (cgm.)	0·01 gm.
1 Milligram (mg.)	0·001 gm.
1 Microgram (μmg, γ)	0·001 mg.

Measure of Capacity

1 Hectolitre (hl.)	100·0 l.
1 Litre (l.)	1·0 l.
1 Centilitre (cl.)	0·01 l.
1 Millilitre (ml. (cc.))	0·001 l.
1 Decimillilitre (dml.)	0·1 ml.
1 Centimillilitre (cml.)	0·01 ml.

Imperial System :

Avoirdupois Weight

1 Ounce (oz.)	16 drachms (dr.)
1 Pound (lb.)	16 oz.
1 Stone (st.)	14 lb.
1 Quarter (qr.)	2 st.
1 Hundredweight (cwt)	4 qrs.
1 Ton	20 cwts.

Measure of Capacity

1 Fluid drachm (fl. dr.)	60 minims
1 Fluid ounce (fl. oz.)	8 fl. dr.
1 Pint (pt.)	20 fl. oz.
1 Quart. (qt.)	2 pt.
1 Gallon (gal.)	4 qt.
(1 gill (quartern)	5 fl. oz.)

Conversion Tables

1 Metre	39·37 inches	1 Pint	0·568 litres
1 Inch	2·54 cm.	1 Ml.	16·39 minims
1 Foot	30·48 cm.	1 Cu. ft.	28·33 litres
1 Litre	1·76 pints		6·235 gallons
	35·2 fl. oz.	1 Cu. in.	16·386 ml.
1 millilitre	0·28 fl. dr.	1 Gallon	4·545 litres

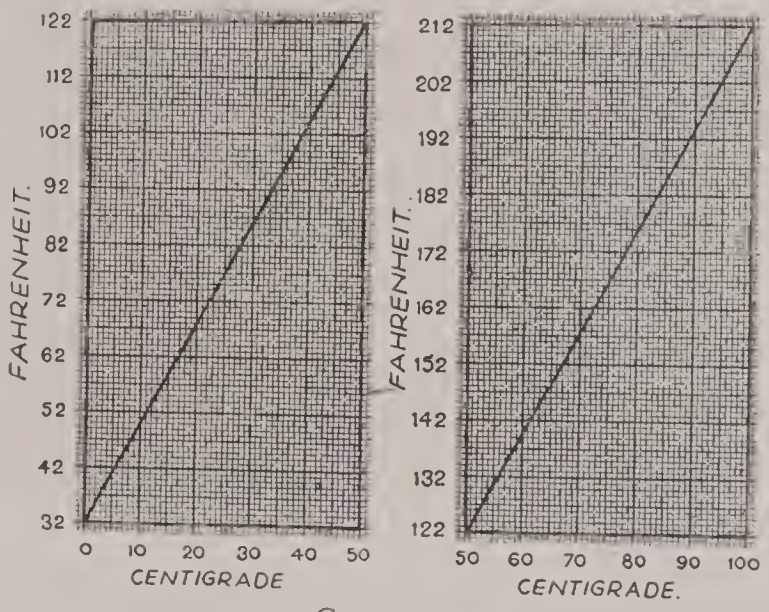
1 Kilogram	2·2 lb. (Av.)
	35·27 oz.
1 Gramme	15·43 grains
1 Oz. (Av.)	28·35 gm.
1 Oz. (Tr.)	31·1 gm.
1 Lb. (Av.)	453·6 gm.

To convert grammes per 100 gm. (per cent.) to grammes per oz. divide by 3·53.

DOMESTIC MEASURE

1 Teaspoonful .	. 1 fl. dr.	1 Wineglassful .	. 2 fl. oz.
1 Dessertspoonful	. 2 fl. dr.	1 Teacupful .	. 5 fl. oz.
1 Tablespoonful	. ½ oz.	1 Tumblerful .	. 8 fl. oz.

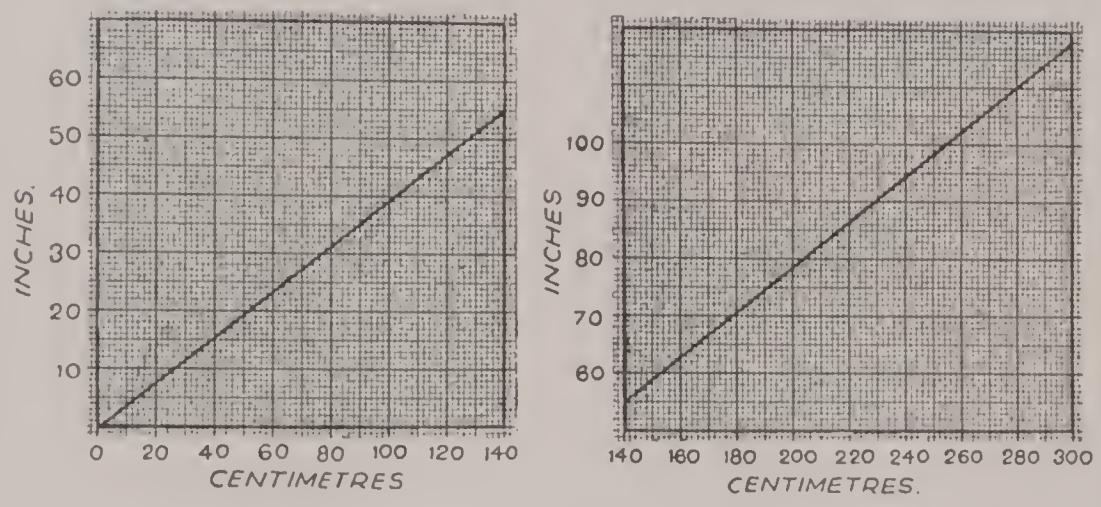
APPENDIX XIX



GRAPH 13

Conversion Graph—"Fahrenheit to Centigrade"

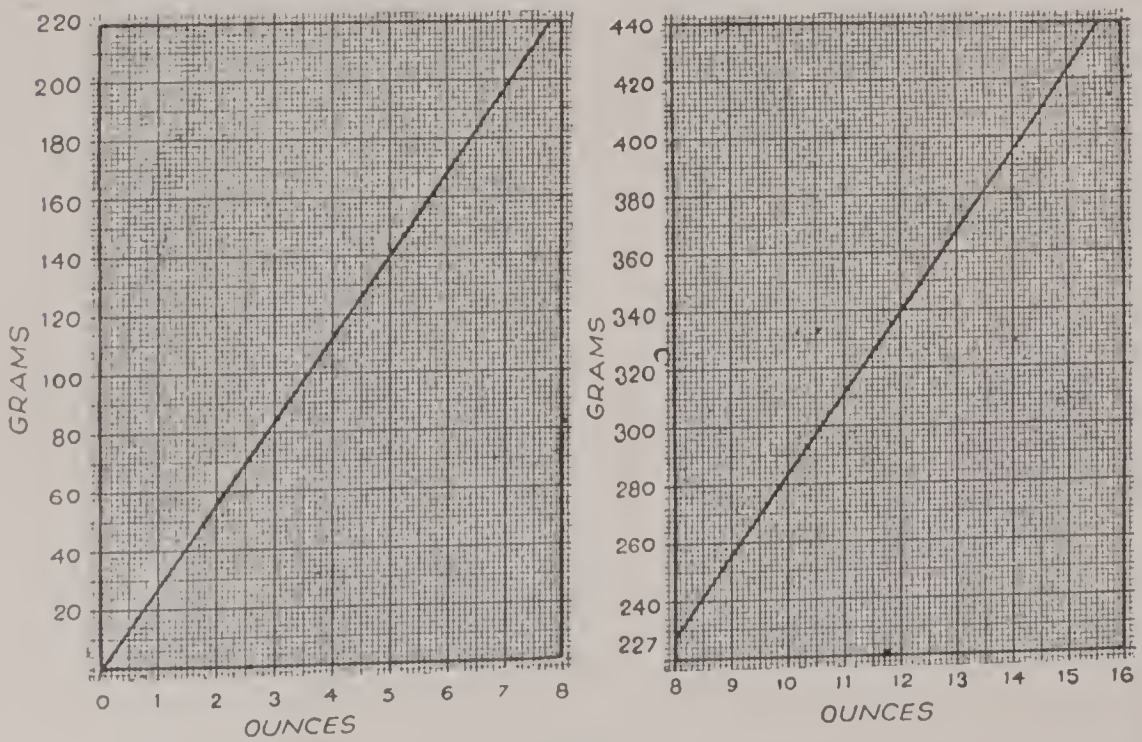
APPENDIX XX



GRAPH 14

Conversion Graph—"Inches to Centimetres"

APPENDIX XXI



GRAPH 15

Conversion Graph—"Ounces to Grammes"

INDEX

Achee poisoning, 302
A.C.H. index, 343
Acid-base balance, 54
Acidic-ash foods, 56
Acids, organic, 56
Adermin, 113
Adlay, 214
  analysis of, 182, 183
Alanine, 10, 12
Alcoholic beverages, 160
Alcoholism, 162
Alfalfa, 188, 189
Alkaline ash foods, 55
Almonds, 229
  analysis of, 192, 193
Alocasia, 218
Alpha-tocopherol, 140
Aluminium, 53
Amaranthus, 223
  analysis of, 188, 189
Amino-acids, 10
Amorphophallus, 218
Anæmia, 39–41
  hookworm, 40, 42
  hyperchromic, 41, 43
  hypochromic, 40, 41
  malarial, 43
  nutritional, 40
  pellagra, 45
  pregnancy, 44
  sprue, 45
Analyses of foods, 180
Aneurin, 88
Angular stomatitis, 103, 277
Anise, 156
Antimony trichloride, test for vitamin A, 333
Apple, analysis of 194
Apricot, analysis of, 194
  dried, 195
Araceæ, 218
Arachidonic acid, 6, 7
Argemone seeds, 229, 300
Aroids, 218
Aromatic leaves, 156
Arrowroot, 222
  analysis of, 186, 187
Arsenic, 54
Asafœtida, 156, 196
Ascorbic acid, 121
  deficiency of, 122
  in foodstuffs, 129
  in urine, 124, 335
Atriplicism, 302
Atwater's calorimeter, 338
Aubergine, 225
Avocado pear, 226
  analysis of, 190, 191

Bael fruit, analysis of, 195
Bamboo shoots, analysis of, 190, 191
Banana, analysis of, 195
Bandakka, analysis of, 190, 191
Barley, 214
  analysis of, 182, 183
Barlow's disease, 123
Basal metabolism, 164
Beans, 215
  analysis of, 184, 185
  French, 190, 191
  haricot, 184, 185
  lima, 184, 185, 305
Beef, 233
  analysis of, 198, 199

Beers (native), 160
Beetles in flour, 325
Beetroot, 221
  analysis of, 186, 187
Benzoic acid, 56
  in fruits, 230
Beriberi, 92
  infantile, 93
  in Japanese Navy, 59
Beverages, 159
Biological adaptation, 32, 35
Biological assays, 67
Biological values, 15
Biotin, 119
  in foodstuffs, 119
Birds, 235
Biscuits, 207
Bitot's spots, 80, 279
Black tongue, 108
Blighia sapida, 302
Boron, 54
Botulism, 316
Brain, 235
Brazil nuts, 192, 193, 229
Bread, 205
  analysis of, 182, 183
  black, 214
  poisoning, 311
  ropy, 311
Bread fruit, 224
  analysis of, 190, 191
Brewer's yeast, 202, 232, 339
Brinjal, 190, 191, 225
Bromine, 54
Buckwheat, 214
  analysis of, 182, 183
Butter, 246
  analysis of, 200, 201

Cabbage, analysis of, 188, 189
Caffeine, 159
Calabash, 192, 193, 226
Caladium, 218
Calciferol, 130
Calcium, 26
  phosphorus ratio, 27, 33
  requirements, 34
Calories, 163
  requirements, 166
Calorimeter, 338
Cambu, 213
Cape gooseberry, analysis of, 194
Capillary fragility, 124, 334
Carbohydrates, 1
Carotemia, 74
Carotene, 73
" Carotinol," 73
Carrots, 221
  analysis of, 186, 187
Cashew nut, analysis of, 192, 193
Cashew fruit, analysis of, 194
Cassava (see manioc) analysis of, 186, 187
Cassein, 12
Cellulose, 4
Cerealine, 212
Cereals, 182, 183, 203
Cevitamic acid, 121
Chastek's paralysis, 67
Cheadle, 60
Cheese, 247
  analysis of, 200, 201
Cheilosis, 104
Chestnuts, 227
  analysis of, 192, 193
Chestnut, water, 227
  analysis of, 192, 193
Chicken, 235
  analysis, 198, 199
Chillies, 156, 196
Cholam, 212
Cholesterol, 8
Choline, 148
  in foodstuffs, 150
Cirrhosis of liver, 157
Citric acid, 56
Citrin, 147
Cobalt, 53

Cobalt, disease in cattle, 53
Cocoa, 159
Coconut, 156, 227
  analysis of, 192, 193
  milk, 228, 253
  oil, 228
  water, 227
  weight of kernel, 355
Cocoyam, 218
Co-enzyme R, 117
Coffee, 159
Colocasia, 218
  analysis of 186, 187
Condiments, 156
  constituents of, 196
Convulsions, 29, 285
  Ca deficiency, 29
Cooking effects on vitamins, 71
  steam, 211
Copper, 49
  in foodstuffs, 50
Coriander, 196
  leaves, 188, 189
Corn cockle poisoning, 311
Corn, broom, 212
  Kaffir, 212
  Sugar, 2
Corn flour, 212
Crab, 236
  analysis of, 198, 199
Cranberry, 230
Crayfish, 198, 199, 236
Crazy pavement eruption, 153
Cretinism, 52
Cryptoxanthin, 73
Cucumber, analysis of, 192
Culebrilla, 153
Cumin, 196
Curds, 239
Curry, 156
Curry leaves, 156
Cysteine, 11
Cystine, 11
Dal (see dhal), 184, 185
Darnel grass, 311
Dasheem, 218
Dates, 231
  analysis of, 195
Decay of teeth, 29, 278
Deficiency, conditioned, 66
Dehydration of foods, 72
Dentition tables, 336
Dermatitis in children, 152, 276
  scrotal, 103, 276
Dextrin, 4
Dextrose, 2
Dhal, 216
  analysis of, 184, 185
Dhurra, 212
Diabetes, 157
Diascorea, 186, 187, 218
Dicoumarin, 144
Dietary surveys, 263
Dietetics, teaching of, 291
Diets, 250
  children's, 258
  infants', 258
  hospital, 251
  labourers', 256
  prison, 255
Dill, 156
Disaccharides, 3
Dorsal median furrow, 275
Drumsticks, 226
  analysis of, 190, 191
Duck, 235
  analysis of, 198, 199
Durian, analysis of, 195

Edible part of foodstuffs, 356
Edo, 218
Egg plant, 225
  analysis of, 190, 191
Egg white injury, 118
Eggs, 248
  analysis of, 198, 199
Eijkman, 59

Energy requirements, 166
Ephestia, 327
Epidemic dropsy, 299
Ergosterol, 8, 131
Ergotism, 319
Eriodictin, 147
Eroded tongue, 104, 277
Erucic acid, 5
Eruption of teeth, 135, 336
Extrinsic factor, 39

Fagopyrism, 311
Farine, 221
Fats, 4
  hydrogenation, 6
  requirements, 168
Fatty acids, 4
  essential, 7
  saturated, 5
  unsaturated, 5
Fenugreek, 157, 196
Figs, analysis of, 195
Figs, dried, analysis of, 195
Filtrate factor, 115
Fish, 235
  analysis of, 198, 199
  dried, 198, 199, 236
  liver oils, 86, 139
  poisoning, 312
  salted, 198, 199, 236
Flavin, 102
Flavonone, 147
Flavoprotein, 102
Flour,
  white, 205
  wholemeal, 205
Fluorine, 54, 306
Fluorosis, 306
Folic acid, 150
Food poisoning, 297
  endogenous, 297
  exogenous, 312
  bacterial, 312
Fructose, 2
Fruits, 194, 230
  dried, 195, 231
Fruit sugar, 2
Fungi (poisonous), 319
Funk, Cashimir, 62

Galactans, 3
Galactose, 2
Garlic, 196
Gelatine, 12
Germinating seeds, 126
Ghee, 246
Gillan's œdema, 153
Gingelly, analysis of, 192, 193
Ginger, 196
Gliadine, 12
Glicinin, 13
Glucose, 2
Glycerol, 4
Glycogen, 4
Glycosides, cyanogenetic, 303
Glycylglycin, 11
Goitre, 52
Goldberger, 107
Goose, analysis of, 198, 199
Gooseberry,
  Cape, 194
  Indian, 129, 194
Gourds, 226
  analysis of, 192, 193
Grains, weights of, 357
Grams, 215
  analysis of, 184, 185
Grape fruit, analysis of, 194
Grapes, 130
Grape sugar, 2
Ground nut, 184, 185, 215
Growth of children, 270
Guava, 129
  analysis of, 194
Gums, spongy, 123, 277

Hæmocuprein, 49
Hæmorrhagica neonatorum, 145

Hæmorrhagic diathesis, 145
Ham, 234
  analysis of, 198, 199
Heart, 234
  analysis of, 198, 199
Heights and weights of children, 270, 342
Hemeralopia,78
Hemicellulose, 4
Hesperidin, 147
Histidine, 10, 13
Hog plum, 194
Holst, 61
Hominy, 212
Honey, 202
Hopkins, 62
Hordein, 13
Hutchinsonian teeth, 307
Hydrocyanic acid, 302
  in foods, 302
  tests for, 353
Hydrogenation of fats, 6
Hypervitaminosis, 138
Hypothrombinemia, 144

Indophenol, 124, 335
Infantile
  morality, 283
  pellagra, 153
Infants, weights of, 289
Inositol, 147
Intrinsic factor, 39
Invert sugar, 3
Iodine, 52
  number of fats, 6
Ipomœa, 188, 189
Iron, 39
  anæmias, 39, 331
  availability of, 46
  in foodstuffs, 48
  in newborn, 41
  requirements, 46

Jaggery, analysis of, 202
Jak fruit, 224
  analysis of, 190, 191
Jam, analysis of, 202
Jambu fruit, analysis of, 194
Jaws, growth of, 29
Jowar, 212

Katabolism, 14
Kephir, 239
Keratitis, 103
Keratomalacia, 81
Khesari, 216, 297
  analysis of, 184, 185
Kidneys, 234
  analysis of, 198, 199
Kouniss, 239
Kramer, 58
Knudsen-Schiötz sign, 275
Kwasiorkhor, 153

Labile methyl group, 149
Lactalbumen, 13
Lactic acid, 90
  in curds, 241
Lactoflavin, 101
Lactose, 3
Ladies' fingers, 225
Lævulose, 2
Lamsiekte, 28
Lathyrism, 297
Lathyrus pea, 216, 297
  analysis of, 184, 185
League of Nations recommendations, 166
Leaves, 188, 189, 222
Leben, 239
Lecithin, 8
Leeks, 186, 187
Lemon, 230
  analysis of, 194
  grass, 156
Lettuce, analysis of, 188, 189
Lima beans, 305
  analysis of, 184, 185

Limes, 230
analysis of, 194
" Limies," 58
Linamarine, 303
Linase, 303
Lind, Captain, 58
Linolenic acid, 5
Linseed, analysis of, 192, 193
Lipoids, 4, 8
Liver, 234
analysis of, 198, 199
cirrhosis of, 157
Lobster, analysis of, 198, 199
Loquat, analysis of, 194
Lotus seeds, analysis of, 182, 183

Macaroni, 207
Mace, 196
Magnesium, 50
Maize, 211
analysis of, 182, 183
Maltose, 3
Mandama, 153, 284, 286
Manganese, 50
Mango, 230
analysis of, 194
Mangosteen, analysis of, 194
Manioc, 218, 220
analysis of, 186, 187
poisoning, 303
Margarine, 6
Marmite, 202, 232
Masai, 21, 272
Maté, 159
Maternal mortality, 290
Matzoon, 239
McCollum, 73
Meat, 233
analysis of, 198, 199
Mellanby, E., 130
Melon, 231
analysis of, 194
Menadione, 143
Mendel, 9, 73
Mentality, 280
Metabolism, basal, 164
Methionine, 13, 149
Methyl group, labile, 149
Methyl-naphthoquinone, 143
Middlings, 204
Milk, 237
analysis of, 200, 201
animals, 38, 238
buffaloes, 200, 201, 238, 242
condensed, 242
fermented, 239
human, 38, 200
humanized, 259
powders, 243
products, 246
proprietary, 245
Mill, rice, 208
Millers' disease, 27
Millets, 212
analysis of, 182, 183
species of, 212
Minerals, 24
in urine, 25
Molybdenum, 54
poisoning by, 306
Monosaccharides, 22
Mosaic eruption, 275
Moths in foods, 327
Muscular dystrophy, 141
Mushrooms, 310
analysis of, 202
Mustard oil, 300
analysis of, 192, 193, 196
seeds, 300,
Mutton, 233
analysis of, 198, 199

Naphthoquinone, 143
Neem, analysis of, 188, 189
Neuritis, 91, 279
Niacin, 107
Nicotinic acid, 107
deficiency, 109

Nicotinic acid, in foodstuffs, 113
Nicotinamide, 107
Night blindness, 79
Nomenclature of deficiency states, 151
Nutmeg, 196
Nutrition, assessment of, 268
Nutritional
  œdema, 22
  surveys, 269
Nuts, 227
  analysis of, 192, 193

Oatmeal, 214
  analysis of, 182, 183
Oats, 213
Œdema, nutritional, 22, 152, 277
Œsophagitis, 279
Oil,
  cod-liver, 86, 139, 202
  halibut, 86, 139, 202
  gingelly, 5
  red palm, 202
  seeds, 192, 193, 227
Okra, 225
Oleic acid, 5
Onion, analysis of, 186, 187
Orange, 230
  analysis of, 194
Organic acids, 55
  in fruit, 230
Osbourn, 73
Osteodystrophia, 27
Osteomalacia, 136
Osteoporosis, 27
Oswego, 212
Oxalic acid, 30
  in foodstuffs, 31
Oysters, analysis of, 198, 199

Paddy, 207
Palm oil, analysis of, 202
Palmyra fruit, analysis of, 194
Palmyra root, analysis of, 186, 187
Pantothenic acid, 115
Papaya, 230
  analysis of, 194
Para-aminobenzoic acid, 120
Paraguay tea, 159
Parsley, analysis of, 188, 189
Parsnip, analysis of, 186, 187
Passion fruit, analysis of, 195
Peaches, analysis of, 194, 195
Pea flour, 217
Pea nut, 215
  analysis of, 184, 185
Peas, 215
  analysis of, 184, 185
Pekelharing, 60
Pellagra, 107, 110
  infantile, 153
Pellagra-like eruption, 276
Pellagroid, 110
Pellagroid-beriberi, 153
Pepper, 196
Pernicious anæmia factor, 39
Persimmon, analysis of, 195
Pigmented conjunctiva, 80
Phenylalanin, 10
Phosphatase, 134
Phosphorus, 26
Photophobia, 104
Phrynoderma, 82, 275
Phytic acid, 30
Pica, 27
Pineapple, analysis of, 194
Pistachio nut, analysis of, 192, 193
Plantain, 225
  analysis of, 190, 191
Plodia, 328
Plums, analysis of, 194
Pollards, 204
Polyavitaminosis, 151
Polysaccharides, 3
Pomegranate, analysis of, 194
Poppy, prickly, 229, 300
Pork, 233
  analysis of, 198, 199
Potassium, 26

Potato, 218
analysis of, 186, 187
Potato, sweet, 218
analysis of, 186, 187
Prawns, 237
analysis of, 198, 199
Prescribing diets, 250
Prolamin, 13
Proteins, 9
allowances of, 168, 173
biological value, 15
chemical nature of, 9
digestive utilisation, 14
requirements, 14, 167
specific dynamic effect of, 20
supplementing, 20
Prothrombin, 144
estimation of, 326
Prunes, 231
analysis of, 195
Prussic acid in foods, 302
tests for, 353
Pseudo-pellagra, 153
Ptomaines, 312
Public health activities, 263
Pulses, 215
analysis of, 184, 185
Pumpkins, 226
analysis of, 192, 193
Pyridoxine, 8, 113
deficiency of, 114
in foodstuffs, 115
Pyruvic acid, 90, 95

Quinones, 143

Radish, 221
analysis of, 186, 187
Ragi, 182, 183, 213
Raisins, analysis of, 195
Rambutan, analysis of, 194
Rape seed, 192, 193
Rathé, 285
Refection, 69, 145
Riboflavin, 39, 101
deficiency of, 103
in foodstuffs, 107
Rice, 207
analysis, 182, 183
bran, 96, 208
cooking of, 210
mill, 208
milled, 208
parboiled, 209
phosphorus pentoxide in, 210
polished, 210
Rickets, 134
" Roughage," 156
Rye, 214
analysis of, 182, 183
Ryvita, 214

Saccharose, 3
Sago, 215
analysis of, 202
Salmonella poisoning, 315
Sambol, 156, 229
Samp, 212
Salt, 25
Saponin, 309
Sapotoxin, 309
Screw pine leaves, 156
Scrotal dermatitis, 104, 276
Scurvy, 122
infantile, 123
Sea salt, 52
Selenium poisoning, 305
Semolina, 207
Senecio, 311
Serine, 11
Sesame oil, 5
Silicon, 54
Shell fish, 198, 199, 236
Snake gourd, 227
Sodium chloride, 25
Sore mouth, 104, 277
Soursop, analysis of, 195

Soya bean, 215
  analysis of, 184, 185
Specific dynamic effect of proteins, 20
Spices, 156
Spinach, analysis of, 188, 189
Spongy gums, 123, 277
Sprue, 66, 110
Standard allowances, 163
  of calcium, 34, 175
  of calories, 172
  of carbohydrates, 174
  of iron, 174
  of proteins, 173
  of vitamins, 175
Staphylococci poisoning, 316
Starch, 3
  sugar, 2
Starvation, 155
Stillbirths, 289
Stomatitis, 104, 277
Sucrose, 3
Sugar, 202
  beet, 3
  cane, 3
Sulphur, 50
Supplementing, 20
Surveys, dietary, 265
  nutritional, 269
Swayback, 49
Sweetbread, 234
Sweet potato, 186, 187, 218
Szent-Györgi, 121, 147

Takaki, 59
Tamarind, analysis of, 196
Tania, 186, 187, 218
Tapioca, 221
Taro, 186, 187, 218
Tea, 159
Teeth, irregularities of, 29
Thiamine, 88
Thiochrome, 96
Toadskin, 82
Tocopherol, 140
Toddy, 94, 160
  analysis of, 202
Tomatoes, analysis of, 190, 191
Tongue, eroded, 104, 277
Trace elements, 51
Tree tomatoes, analysis of, 194
Tribolium, 325
Tripe, 235
Tryptophane, 10
Turnip, 186, 187

Ultra-violet light, 131

Vascularization of sclerotics, 104
Vegetable marrow, analysis of, 192, 193
Vegetarianism, 22
Vermicelli, 207
Vicia sativa, 297
Viosterol, 130
Vital statistics, 283
Vitamin A, 73
  chemical nature of, 73
  international unit, 85
  pathology, 77
  skin eruption, 82
  tests, 83
  value in foods, 86
Vitamin B1 (thiamine), 88
  beriberi, 92
  chemical nature of, 89
  in foods, 99
  unit of, 97
Vitamin B2 (see riboflavin), 101
Vitamin B6 (see pyridoxine), 113
Vitamin B_x, 120
Vitamin B (complex), 88
Vitamin C (see ascorbic acid), 121
Vitamin D, 130
  chemical nature of, 131
  international unit, 137
  rickets, 134
" Vitamine," 62
Vitamin E, 139
Vitamin F, 64, 101

Vitamin G, 101
Vitamin H, 117
Vitamin K, 143
Vitamin L, 151
Vitamin P, 147
Vitamin PP, 107
Vitamins, history of, 57
Vomiting sickness, 302

Walnuts, 229
  analysis of, 192, 193
Weaning, 258
Weevils, 321
Weights
  of children at birth, 287
  of grain, 357
Weights and measures, 358
Wheat, 204
  analysis of, 182, 183
Wood apple, 195

Xerophthalmia, 78

Yams, 218
  analysis of, 186, 187
Yeast, 202, 231, 339
Yerba, 159
Yoghourt, 239

Zein, 12
Zinc, 53

Printed in Great Britain by William Clowes & Sons, Limited, Beccles, for Baillière, Tindall & Cox.

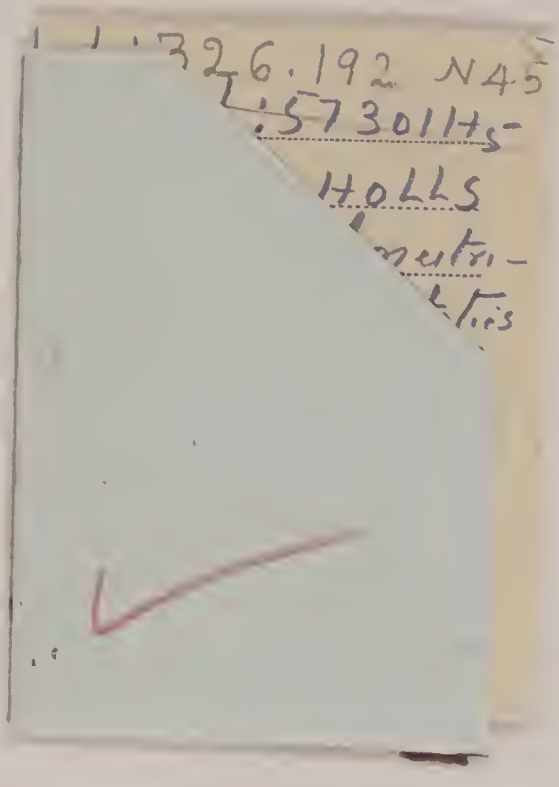
CHECKED
27.5.97

C. F. T. R. I. LIBRARY, MYSORE

CHECKED
2008

VERIFIED
2013

CFTRI LIBRARY
707


1 1 326.192 N45
.5730 11 Hs-
HOLLS
nutri-
tics